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CHEMISTRY

OF

ORGANIC BODIES.

VEGETABLES.

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ORGANIC BODIES.

VEGETABLES.

BY THOMAS THOMSON, M.D.

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PREFACE.

THE object of the present volume is, to lay before the British chemical public, a pretty full view of the present state of the chemistry of Vegetable Bodies. This branch of the science has made so much progress of late years, that a very wide and inviting field has been laid open. Several hundred new substances have either been discovered, or their characters have been determined with such precision, and their composition investigated with such accuracy, as to give a pretty accurate idea of their constitution, and of their connexion with each other. These ultimate analyses, with a very few exceptions, have been all made upon the continent, and chiefly in Germany and France. British chemists have scarcely entered upon the investigations. Dr Prout, indeed, in 1827, published an analysis of sugar, starch, lignin, and some of the vegetable acids. His results were accurate, but his apparatus was of too complex a nature to warrant trust-worthy results in the hands of ordinary experimenters. Within these very few years, Mr Kane of Dublin, and Dr Gregory, who had been trained to vegetable analysis in Liebig's laboratory in Giessen, have begun the investigation of vegetable bodies. Already various important facts have been ascertained by them; and, if they continue their investigations, there can be no doubt, from their well known sagacity and dexterity, that many important discoveries in this interesting branch of chemistry will result from them.

The present volume, by exhibiting a pretty complete view of the present state of vegetable chemistry; and, by presenting together the most important facts that have been ascertained, will, I trust, be of some use to those British chemists, who may wish to enter upon this very interesting field of investigation.

I had intended at first to have given a minute detail of the method employed for obtaining an accurate analysis of a vegetable substance. But, after considering the subject maturely, I was induced by two circumstances to delay these details till the publica-

tion of my next volume on Animal Substances, which will complete my plan. The first of these is the great and unexpected size to which this volume has swelled. This has rendered it necessary to leave out every thing that did not constitute an essential part of the subject.

The second circumstance, which induced me to delay the description of the mode of the analysis to the next volume, is the very minute details of that method which have been given by Liebig and Dumas, the two chemists to whom we are indebted for the greatest number, and the most accurate vegetable analyses which we possess. Liebig contrived the most important part of the apparatus; and in his *Handwörterbuch* (*dictionary*) *der reinen und angewandten Chemie*, under the word *Analyse, organische*, he has given such minute details of the whole steps of the process, accompanied by accurate figures of the apparatus, that every chemist, who peruses it with care, can feel no difficulty in analyzing any vegetable substance whatever. Professor Liebig has published this article as a separate pamphlet. Were any person to favour us with an English translation of it, he would contribute essentially to promote the prosecution of vegetable chemistry in Great Britain, and would be conferring an important favour on the British chemical public. Dumas, in the Introduction to the 5th volume of his *Traité de Chimie appliquée aux Arts*, has also given a minute detail of the methods of analyzing vegetable bodies, and pointed out various methods of checking the errors to which the method is liable, and of deducing the atomic weight from methods independent of the elementary analysis. His observations are highly worthy of an attentive perusal, and cannot fail to communicate much useful information. Professor Mitscherlich of Berlin, has made some attempts to improve the apparatus of Liebig; though I doubt whether the additional accuracy is not more than compensated by the complicated nature of his improvements. To him, as well as to H. Rose, Pelouse, and some other young French chemists, we are indebted for a great number of accurate vegetable analyses.

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INTRODUCTION.

ALL substances, so far as we have an opportunity of examining them, belong to one or other of the three kingdoms of nature, distinguished by the names of the *mineral*, *vegetable* and *animal kingdoms*. The bodies belonging to the first of these have been described, as far as their chemical properties are concerned, in the preceding volumes of this work. We come now to the Chemistry of *vegetable* and *animal bodies*.

It is well known that every vegetable and animal constitutes a machine of greater or less complexity, composed of a variety of parts dependent on each other, and acting all of them to produce a certain end. Vegetables and animals on this account are called *organized* beings; and the chemical constituents of which they are composed are called the constituents of *organized beings* or *organized bodies*, to distinguish them from the constituents of the *mineral* kingdom, which consist merely of aggregates of atoms combined together without constituting an *organized* structure.

The chemical principles of which animals and vegetables are composed are exceedingly numerous. But we can seldom obtain them in a state of such purity as to enable chemists to examine their properties with accuracy, unless when they are capable of crystallizing or of entering into definite compounds with acids or alkalies. Hence the great difficulty which has attended the investigation of oils, glues, albumen, &c., which we have no means of procuring in a state of absolute purity.

The chemical principles of organized bodies are all compounds, and consist sometimes of two, sometimes of three, and sometimes of four, simple bodies united together; but seldom of more. These simple bodies are *hydrogen*, *carbon*, *oxygen* and *azote*, which may be considered as constituting, in a great measure, the basis of the animal and vegetable kingdoms.

I. Organized principles composed of two ingredients are of four kinds.

(I.) 1. Composed of hydrogen and carbon. Thus oil of turpentine is a compound of C^{10} H^{8}*

* The atom of the different simple bodies is denoted by the first letter of the name, or in certain cases by two or even three letters to prevent ambiguity, and the number of atoms of each by the figure placed on the right side of the letters. Thus C^{10} H^{8} means a compound of

10 atoms carbon
8 atoms hydrogen.

2. Composed of hydrogen and oxygen. Thus water is a compound of H O.

3. Of carbon and oxygen. Thus oxalic acid is a compound of C^2 O^3.

4. Of carbon and azote. Thus cyanogen is C^2 Az.

Organized principles composed of three constituents are much more numerous than those composed of two.

1. The most common constituents are *carbon*, *hydrogen* and *oxygen*. The greater number of the acids, alcohol, ethers, sugars, gums, &c., are thus constituted. When carbon is saturated with oxygen it unites with two atoms, and the union is attended with the phenomena of combustion. Hydrogen by combustion forms water containing one atom of hydrogen united to one atom of oxygen. But in organized principles containing hydrogen, carbon and oxygen, the oxygen never amounts to so much as three atoms for two atoms of the other constituents. Sometimes it is enough to convert the hydrogen into water, or the carbon into carbonic acid, but never to convert both at once into water and carbonic acid. Hence it happens that all these compounds of three ingredients, though they contain oxygen, are still combustible. When heat is applied to them, if we raise it to a certain point, which is different in each body, a portion of carbon unites to a portion of oxygen, and flies off in the state of carbonic acid, or a portion of oxygen unites to hydrogen and escapes under the form of water. What remains is a new organized principle.

2. Some few organized bodies are composed of carbon, hydrogen, and azote. Thus azulmic acid seems to be C^5 H Az^2.

3. Some are supposed to be composed of carbon, azote, and oxygen. Thus carbazotic acid is C^{15} Az^3 O^{15}.

The organic principles composed of four constituents, consist of carbon, hydrogen, azote and oxygen united in various proportions. Thus *aspartic acid* is C^8 H^7 Az O^8. Almost the whole of the alkaloids contain these four constituents.

The number of atoms of azote contained in these compounds is generally small compared with that of the other three constituents. And there is almost always a great preponderance in the atoms of carbon and hydrogen over those of azote and oxygen. The richest body in azote known is *melon*, which is composed of C^6 Az^4.

It has been supposed by some chemists that there is an essential difference between the affinities which unite the atoms constituting organic principles, and those which unite the atoms of unorganized

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The meaning of the letters will be understood by the following table :—

C is carbon
H is hydrogen
Az is azote
O is oxygen
Chl. is chlorine
Br is bromine.
I is iodine
S is sulphur
N is sodium
K is potassium
Ph is phosphorus.

bodies—that there is some unknown power besides chemical affinity, which interferes with, and regulates the combinations and decompositions of organized bodies, which is wanting in those that are unorganized. But I can see no evidence for any such opinion. The great difference between the two classes of bodies consists in this, that the organized are much more complicated in their structure, containing a much greater number of atoms than the unorganized. Hence they are much more unstable, much more easily decomposed, and much more liable to decomposition than unorganized bodies.

But the reason of this I consider to be very obvious. Organic principles are made by the processes connected with vegetable and animal life. They constitute the results proceeding from the chemical skill of the Creator of plants and animals, which is infinitely greater than ours can pretend to be. Because we have not hitherto been able to make compounds consisting of the various atoms constituting mineral bodies, as complicated as those which exist in the animal and vegetable kingdoms, it does not follow that such complicated compounds are impossible, or that they may not hereafter be produced as chemical skill improves. It is very probable that silicon, the metals, sulphur, chlorine, bromine, iodine, phosphorus, &c., will hereafter give rise to bodies as complicated in their structure as the vegetable acids, alkaloids, oils, resins, sugars, and other organized compounds, which at present appear to differ so far from mineral compounds. Nor is it at all unlikely that chemists may hereafter acquire skill enough to be able to form, artificially, the various organic principles, such as sugar, gum, &c., which at present are obtained ready formed from the vegetable or animal kingdom.

The prevailing opinion at present among chemists is, that *binary* compounds alone exist: that is to say, that one electro-negative atom is only capable of combining with one electro-positive atom. Two of these binary compounds may combine together, making a new binary compound consisting of four atoms. Two of these new binary compounds may combine with each other, making a new binary compound consisting of eight atoms. And in this way binary compounds may be formed as complicated as any that exist. But I do not see the evidence upon which this opinion rests. The most stable of the unorganized principles indeed as barytes, lime, strontian, magnesia, potash, and soda, are binary compounds, being composed each of an atom of oxygen united to an atom of the respective metals, which constitute the bases of these bodies. But sulphuric acid, which is scarcely less stable than these bodies, is a quaternary compound, being composed of one atom of sulphur united to three atoms of oxygen, and nitric acid is a sextenary compound of one atom of azote with five atoms of oxygen. Now, I cannot conceive any reason for not believing, that in sulphuric acid the three atoms of oxygen surround the atom of sulphur in the

way long ago suggested by Mr. Dalton, forming a complex atom, which may be represented thus,  in which ⊛ represents an atom of sulphur, and ○ an atom of oxygen.

The truth is, that in the present state of our knowledge, we have no means of knowing how the numerous atoms that constitute organic principles are grouped together. It is in vain therefore to speculate upon the subject. The present business of our science is to accumulate facts, which may gradually enlighten us respecting this most obscure but important branch of Chemistry.

The Chemistry of vegetable principles has made considerably greater progress than that of animal principles; chiefly because the former have a greater tendency to crystallize, and, in consequence of this property, can be more easily obtained in a state of purity than the latter. It will be proper on this account to treat of each separately. Though I do not believe that there is any essential difference between them. The time will certainly come when animal and vegetable principles will be arranged together according to their characters. But till they have been more thoroughly investigated there is an advantage attending the separate consideration of each; because it facilitates their arrangement, which is at present attended with inseparable difficulties. The Chemistry of *vegetable principles* will occupy the present volume; that of animal principles will follow in another, which will conclude the work.

PART I.

CHEMISTRY OF VEGETABLE BODIES.

The object of this very important branch of Chemistry, which has made unlooked-for progress during the last five or six years, is to give an account of the numerous *principles* or definite compounds which exist in the vegetable kingdom, or which may be formed from vegetable bodies by processes which are becoming daily more varied and better understood by chemists. Many of these substances are capable of crystallizing, and in this way can be procured in a state of purity. This is the case with most of the vegetable acids and alkaloids, with sugar and some other substances not easily classified. Others are volatile, and are formed or driven off at particular temperatures. Alcohol, ethers, and volatile oils are in this predicament. Pretty frequently several of these volatile bodies occur together, and in such cases we have scarcely the means of obtaining them in a state of purity unless when they enter into definite and crystallizable compounds with some other substance.

It is not unlikely that all the vegetable principles may be found hereafter to be capable of entering into definite compounds with other bodies, and that they will be ultimately possessed of the character of *acids* or *bases*. But there are a good many vegetable principles, which so far as our present knowledge extends, do not seem capable of forming any such definite compounds, thus *caoutchouc* neither combines with acids nor bases. We must consider such bodies as neutral.

There exist also several groups of bodies which have been distinguished by a common name, some of which neutralize acids and therefore ought to constitute bases, while others belonging to the same group neutralize *bases*, and therefore ought to constitute acids: while a considerable number of the bodies belonging to the group has been so imperfectly examined that we do not know whether they be acids or alkalies. This is the case with the group of bodies distinguished by the name of volatile oils. *Oil of turpentine* saturates muriatic acid, and therefore is a base; while *oil of cloves* saturates bases, and therefore is an acid. But many of the other volatile oils have been so imperfectly examined that we could not venture to place them either among bases or acids.

In consequence of this imperfect state of our knowledge of these and various other groups similarly circumstanced, I have been under

the necessity of forming a temporary *class* under the name of *intermediate bodies*. This class will disappear as it has done from the *unorganized* bodies, when our investigations of vegetable principles have made greater progress.

In this work, then, I shall arrange all the vegetable principles with which we are acquainted under the four following classes:—

Class I. Acids.
II. Alkalies.
III. Intermediate principles.
IV. Neutral principles.

It has been observed in the introduction, that we have no precise notions of the way in which the numerous atoms constituting various vegetable principles arrange themselves. Some little light has indeed been thrown upon the subject by the late investigations of Wöhler, Liebig, Pelouze and Dumas. And it will be proper before proceeding to detail the characters of the various vegetable principles, to lay the results of these investigations before the reader.

1. *Theory of Amides*, or *Amidets*.

The composition of oxalic acid is represented by the formula $C^2\ O^3$, and that of ammonia by $Az\ H^3$. We may therefore represent oxalate of ammonia by $C^2\ O^3 + Az\ H^3$. In the year 1830 Dumas observed, that when crystallized oxalate of ammonia is distilled there is obtained, among other products, a white tasteless powder, which he distinguished by the name of *oxamide*.* On analysing this white powder, which will be described in a subsequent part of this volume, he found it composed of $C^2\ O^2 + Az\ H^2$. It is therefore oxalate of ammonia deprived of an atom of water. When heated with potash, ammonia is disengaged and oxalate of potash formed. By this treatment, therefore, it is converted into oxalate of ammonia, and of course must have resumed the atom of water which it had lost.

The term *amide* has been generalized by chemists, and is applied to all those anhydrous compounds of an acid and ammonia which by heat may be deprived of an atom of water: or to all those compounds which, by the addition of an atom of water, can be converted into a salt of ammonia.

Benzoic acid consists of . .	$C^{14}\ H^5\ O^3$
Ammonia	$H^3\ Az$
Benzoate of ammonia of	$C^{14}\ H^5\ O^3 + H^3\ Az$

Now, by a process, which will be explained in a subsequent part of this volume, Wöhler and Liebig obtained a substance to which they gave the name of benzamide, composed of $C^{14}\ H^5\ O^2 + H^2\ Az$, so that it differed from benzoate of ammonia by containing H O or an atom of water less.

Now, as oxalate of ammonia and benzoate of ammonia are in all probability binary compounds, being composed of the acid and alkali thus,

* A contraction of oxalate of ammonia.

Oxalate of ammonia . . $C^2\ O^3 + H^3\ Az$
Benzoate of ammonia . $C^{14}\ H^5\ O^3 + H^3\ Az$

it has been inferred, that oxamide and benzamide are also binary compounds, thus,

Oxamide . . . . $C^2\ O^2 + H^2\ Az$
Benzamide . . . $C^{14}\ H^5\ O^2 + H^2\ Az$

If this be admitted, it will follow, that $C^2\ O^2$ and $C^{14}\ H^5\ O^2$ are compounds capable of existing and of combining with other bodies: and likewise, that there is such a compound as $H^2\ Az$.

To give another example:

Aspartate of ammonia is $C^8\ H^5\ Az\ O^6 + H^3\ Az$
Asparagin or asparamide $C^8\ H^5\ Az\ O^5 + H^2\ Az$

Liebig applies the name *amide* to the hypothetical compound of two atoms hydrogen and one atom azote. If we heat potassium to the point of fusion and pass over it a current of dry ammoniacal gas, hydrogen gas is evolved, and the potassium at first increases greatly in bulk, the metallic lustre gradually vanishes, and it is converted into a clear liquid, which on cooling concretes into a grey silky mass crystallized in plates. If we add water to this mass it is instantly converted into potash and ammonia. It is considered as *potassamide*, or a compound of

1 atom potassium . . . . K
1 atom of . . . . . $H^2\ Az$

Potassamide . . . . $K+H^2\ Az$
Add 1 atom water . . . H O
And we have . . . . K O+H^3 Az

or an atom of potash and an atom of ammonia.

Sodium by the same process is converted into sodamide=N+H^2 Az.

According to Mr. Kane, the *Mercurius precipitatus albus* of the Pharmacopœia is a mercuramide, or a compound of Hg+H^2 Az.

Dumas has given to these compounds the name of *amidet*. Thus *oxamide* he calls amidet of oxide of carbon $H^2\ Az+C^2\ O^2$; $C^2\ O^2$ being a compound similar in constitution to oxide of carbon, which is C O.

Potassamide is amidet of potassium $H^2\ Az+K$, and sodamide and mercuramide are amidets of sodium and mercury.

There is a striking analogy between the amidets and the chlorides. The addition of an atom of water converts both into salts. Thus chloride of sodium is N Chl. Add an atom of water H O and we get N O+H Chl, or muriate of soda.

Dumas gives another example of an amidet in urea, the composition of which may be represented thus: $C^2\ O^2+H^4\ Az^2$

Add 2 atoms water . . . $O^2\ H^2$

We have . . . . $C^2\ O^4+H^6\ Az^2$

or two atoms carbonic acid and two atoms ammonia, making together carbonate of ammonia.*

* Dumas' Chimie Appliqué, v. 83.

2. *Theory of Benzoyl.*

In treating of *benzoic acid* in a subsequent part of this volume, an account will be given of the remarkable train of discoveries made by Wöhler and Liebig, while investigating the properties and constitution of the volatile oil of bitter almonds. From these discoveries they have been led to infer that the basis of benzoic acid is a substance, to which they have given the name of *benzoyl*, composed of

$C^{14}\ H^5\ O^2$

The oil of bitter almonds is a hydret or, $C^{14}\ H^5\ O^2+H$
Benzoic acid is an oxide or . $C^{14}\ H^5\ O^2+O$

They obtained also

Chloride of benzoyl . . $C^{14}\ H^5\ O^2+Chl$
Bromide of benzoyl . . $C^{14}\ H^5\ O^2+Br$
Sulphuret of benzoyl . . $C^{14}\ H^5\ O^2+S$
Cyanide of benzoyl . . $C^{14}\ H^5\ O^2+C^2\ Az.$

These curious discoveries render it almost certain that benzoyl exists as a separate compound, and that it is capable of combining with the supporters of combustion and cyanogen, and likewise with hydrogen, sulphur, and doubtless other simple substances or compounds.

M. Löwig has given us a similar set of compounds in the volatile oil of spirœa ulmaria. This volatile oil is a hydret of spiroil—a supposed base not yet insulated.

Spiroil . . . . $C^{12}\ H^5\ O^4$
The oil or hydret . . $C^{12}\ H^5\ O^4+H$
Chloride of spiroil . . $C^{12}\ H^5\ O^4+Chl$
Bromide of spiroil . . $C^{12}\ H^5\ O^4+Br$
Iodide of spiroil . . . $C^{12}\ H^5\ O^4+I$
Spiroilic acid . . . $C^{12}\ H^5\ O^4+O^4$

Analogy leads to the inference that other (probably all the) vegetable acids have, like benzoic acid, a base, and that the acid is a compound of that base with oxygen. Thus, since

Peucedanin is . . . . $C^4\ H^2+O$
Succinic acid . . . . $C^4\ H^2+O^3$
Malic and citric acids . . $C^4\ H^2+O^4$
Tartaric and racemic acids . . $C^4\ H^2+O^5$

may it not be inferred, that they have for a common base $C^4\ H^2$?

The common base of the alkalies, cinchonina, quinina, and arecina, seems to be $C^{20}\ H^{12}\ Az$.

Cinchonina is . . . $C^{20}\ H^{12}\ Az+O^{1\frac{1}{2}}$
Quinina . . . . $C^{20}\ H^{12}\ Az+O^2$
Arecina . . . . $C^{20}\ H^{12}\ Az+O^3$

3. *Theory of Ethers.*

A discussion respecting the constitution of ethers has been carried on with much animation, between M. Dumas on the one side, and M. Liebig on the other. According to Dumas, the base of ether is $C^4\ H^4$; or what I distinguished in the *Chemistry of Inorganic*

Bodies by the name of tetarto-carbohydrogen. Sulphuric ether is $C^4\ H^4+HO$; oxalic ether is $(C^4\ H^4+HO)+C^2\ O^3$, and so on of the others.

According to Liebig on the other hand, the radical of ether is $C^4\ H^5$. Sulphuric ether is an oxide of $C^4\ H^5$, and is represented by $C^4\ H^5+O$: or (for shortness' sake) by $C^4\ H^5\ O$. Alcohol is a hydrate of sulphuric ether, or $C^4\ H^5\ O+HO$.

The radical of ether, or $C^4\ H^5$, is capable of combining with chlorine, bromine, and iodine, and forms chloric, bromic, and iodic ethers, composed as follows:—

Chloric ether . . .	$C^4\ H^5+2$ Chl
Bromic ether . . .	$C^4\ H^5+2$ Br
Iodic ether	$C^4\ H^5+2$ I

All the oxygen acid ethers are combinations of an atom of sulphuric ether, which possesses the characters of a base with an atom of the acid. Thus,

Nitrous ether is . .	$C^4\ H^5\ O+Az\ O^3$
Acetic ether . .	$C^4\ H^5\ O+C^4\ H^3\ O^3$
Oxalic ether . .	$C^4\ H^5\ O+C^2\ O^3$
Benzoic ether . .	$C^4\ H^5\ O+C^{14}\ H^5\ O^3$
Formic ether . .	$C^4\ H^5\ O+C^2\ H\ O^3$
Mucic ether . .	$C^4\ H^5\ O+C^6\ H^4\ O^7$
Citric ether . .	$C^4\ H^5\ O+C^4\ H^2\ O^4$
Succinic ether . .	$C^4\ H^5\ O+C^4\ H^2\ O^3$
Chlorocarbonic ether .	$C^4\ H^5\ O+C^2$ Chl O^3
Chlorocyanic ether .	$C^4\ H^5\ O+C^2$ Az Chl.
Œnanthic ether . .	$C^4\ H^5\ O+C^{14}\ H^{13}\ O^2$

What have been considered as alcohol acids are merely combinations of one atom of ether acting as a base with two atoms of the acid. Thus,

Althionic acid is .	$C^4\ H^5\ O+2\,(S\ O^3)$
Phosphovinic acid .	$C^4\ H^5\ O+2\,(Ph\ O^{2\frac{1}{2}})$
Oxalovinic acid .	$C^4\ H^5\ O+2\,(C^2\ O^3)$
Tartro-vinic acid .	$C^4\ H^5\ O+2\,(C^4\ H^2\ O^5)$

They ought rather to be considered as salts, consisting of two atoms acid united to one atom base than as acids *sui generis*; accordingly one atom of barytes added to an integrant particle of each of these acids renders them neutral, because the atom of ether neutralizes the other atom of the acid present.

Of these two views, I am disposed to prefer that of Liebig as the simplest, and as agreeing best with the phenomena. Liebig has extended his theory much farther, and made it apply to sugars, mercaptan, xanthic acid, &c.

Common sugar is . . .	$C^{12}\ H^{10}\ O^{10}$

Now it is resolvable into

2 atoms ether	$C^8\ H^{10}\ O^2$
4 atoms carbonic acid . . .	$C^4\ \ \ O^8$
	$C^{12}\ H^{10}\ O^{10}$

We may, therefore, represent common sugar by this formula: $2\ (C^4\ H^5\ O)+4\ (CO^2)$.

Anhydrous sugar of grapes is $C^{12}\ H^{12}\ O^{12}$. It may be represented by $2\ (C^4\ H^5\ O)+4\ (CO^2)+2\ (HO)$, and common grape sugar is $2\ (C^4\ H^5\ O)+4\ (CO^2)+4\ (HO)$.

Mercaptan is $C^4\ H^5\ S\ H$ (sulphuretted hydrogen).

And xanthic acid $C^4\ H^5\ O+2\ (S^2\ C)$ (bi-sulphuret of carbon).

Alcohol is $C^4\ H^5\ O+HO$.

4. *Theory of Pyracids.*

There are several vegetable acids which, when distilled, undergo decomposition, and new acids are generated by the process, which have been distinguished by the name of *pyracids*. Thus *tartaric* acid, when so treated, yields*p yrotartaric* acid; *mucic* acid gives *pyromucic; gallic*, *pyrogallic*, and *kinic*, *pyrokinic* acid.

Now, M. Pelouze has observed, that the nature of the decomposition is regulated by the degree of heat applied. When the heat is not too high, the acid is resolved into a pyracid, carbonic acid and water, or sometimes into a pyracid, and one or other of the two last products. Thus, when tannin is distilled at a heat of 482°, it is resolved completely into carbonic acid, water, and metagallic acid.

Tannin being $C^{18}\ H^8\ O^{12}$, 3 atoms of tannin are $C^{54}\ H^{24}\ O^{36}$. Now these three atoms are resolved by the heat into

6 atoms carbonic acid	=	$C^6\ \ O^{12}$
8 atoms water	=	$H^8\ O^8$
8 atoms metagallic acid	=	$C^{48}\ H^{16}\ O^{16}$
		$C^{54}\ H^{24}\ O^{36}$

When gallic acid is distilled at 419°, it is converted into pyrogallic acid and carbonic acid.

Gallic acid is	.	$C^7\ H^3\ O^5$
Pyrogallic acid is	.	$C^6\ H^3\ O^3$
Carbonic acid is	.	$C\ \ O^2$
		$C^7\ H^3\ O^5$

At the temperature of 482° no pyrogallic acid is formed, but only metagallic acid, water and carbonic acid.

1 atom gallic acid is	.	$C^7\ H^3\ O^5$
1 atom metagallic acid	=	$C^6\ H^2\ O^2$
1 atom carbonic acid	=	$C\ \ O^2$
1 atom water	=	$H\ O$
		$C^7\ H^3\ O^5$

When malic acid is distilled at a low heat, it is resolved into maleic acid and water.

Malic acid is . .	$C^4\ H^2\ O^4$	
Maleic acid . .	$= C^4\ H\ O^3$	
Water . .	$= \quad H\ O$	
	$C^4\ H^2\ O^4$	

When acetate of barytes is distilled, the acid is resolved into carbonic acid, which remains combined with the barytes and pyroacetic spirit or *acetone*.

Acetic acid is . .	$C^4\ H^3\ O^3$
Acetone is . .	$C^3\ H^3\ O$
Carbonic acid is . .	$C \quad O^2$
	$C^4\ H^3\ O^3$

Sometimes the saturating power of a vegetable acid is not altered by converting it into a pyroacid; sometimes, according to Pelouze, it is reduced to one-half.*

From these very important and curious observations, for which we are indebted to M. Pelouze, it has been inferred, that gallic acid is a compound of pyrogallic acid and water, and so of the rest. But I cannot see upon what evidence that opinion rests. An atom of tannin cannot be resolved into metagallic acid, carbonic acid and water, though these are the products when the acid is distilled at 482°. It is much more probable, that by the temperature applied, a certain portion of the carbon, or hydrogen, or of both, undergoes combustion, and that the remaining atoms arrange themselves so as to constitute the pyroacids.

5. *Theory of Substitutions.*

Oxygen, chlorine, bromine and iodine may be made to unite with various compound bodies, while at the same time these bodies give out hydrogen. Thus when dry chlorine gas is passed into pure oil of bitter almonds, which is composed of $C^{14}\ H^5\ O^2+H$, it loses its atom of hydrogen which constituted it a hydret, for which an atom of chlorine is substituted, making a compound consisting of $C^{14}\ H^5\ O^2+Chl.$ which is a chloride of benzoyl. Dumas has generalized this and various analogous facts, and drawn from them the following general conclusions:—

1. When a body containing hydrogen is subjected to the dehydrogenizing action of oxygen, chlorine, bromine, or iodine, for every atom of hydrogen that it loses it gains an atom of oxygen, chlorine, bromine or iodine.

2. When the hydrogenous body contains water, this last body loses its hydrogen without any thing being replaced. If, after this, any hydrogen be abstracted, it is replaced by a corresponding number of atoms of oxygen, chlorine, &c.

* Ann. de Chim. et de Phys. lvi. 303.

Dumas gives the following examples of these rules:—

(1.) Dry oxalic acid is $C^2\ O^3+H\ O$. That is to say, an atom of oxalic acid and an atom of water. The water, when the acid is treated with nitric acid, loses its hydrogen, and there remains $C^2\ O^4$, that is two atoms of carbonic acid, into which it is well known that oxalic acid is converted by the action of nitric acid.

I think that the phenomena would be explained in a simpler way in this case by considering the water of the oxalic acid to be inert, and that the nitric acid gives out an atom of oxygen to the anhydrous oxalic acid, and thus converts it into carbonic acid. For if we take crystallized oxalic acid composed of $C^2\ O^3+3\ H\ O$ the result is the same. Here two atoms of the combined water are admitted to be inert. Why should they not all three be in the same predicament?

(2.) Formic acid by the action of oxides of mercury or silver is converted into carbonic acid. Formic acid is $C^2\ H\ O^3$. Here the oxygen of the oxides forms water with the hydrogen of the acid, and adds an atom of oxygen, making $C^2\ O^4$, which is two atoms of carbonic acid.

(3.) Alcohol, by the action of the atmosphere, is converted into acetic acid. Alcohol is $C^4\ H^5\ O+H\ O$, and crystallized acetic acid is $C^4\ H^3\ O^3+H\ O$. Here, if we neglect the atom of water in both, which is not affected by the action, we see that two atoms of hydrogen are replaced by two atoms of oxygen. So that the change corresponds exactly with Dumas' law.

(4.) Alcohol, by the united action of sulphuric acid and binoxide of manganese, is converted into formic acid. Alcohol is $C^4\ H^5\ O+H\ O$. If four atoms of the hydrogen are replaced by four atoms of oxygen we have $C^4\ H^2\ O^6$, which is two atoms of formic acid.

(5.) The chloride of olefiant gas, usually called *Liquor of the Hollanders*, is a compound of $C^2\ H^2\ Chl$ or $C^4\ H^4\ Chl^2$. When mixed with chlorine gas and exposed to the action of solar light it loses all its hydrogen, which is replaced by as many atoms of chlorine, and it becomes $C^4\ Chl^6$ or sesquichloride of carbon.

(6.) When hydrocyanic acid is exposed to the action of chlorine, it loses its atom of hydrogen, which is replaced by an atom of chlorine. Hydrocyanic acid is $C^2\ Az+H$. It becomes $C^2\ Az+Chl$ or chlorocyanic acid.

(7.) The essential oil of cinnamon is converted by the action of the air or oxygen gas into cinnamonic acid. Oil of cinnamon, according to the analysis of Dumas and Peligot, is $C^{18}\ H^9\ O^2$ and cinnamonic acid is $C^{18}\ H^7\ O^3$. Here it loses H^2 and gains O, which does not quite agree with Dumas' theory. But I consider the true composition of the oil of cinnamon to be $C^{18}\ H^8\ O^3$, which would bring it under the formula.

These examples are amply sufficient to explain the nature of Dumas' empyrical formula. Were it to hold universally, it would indicate, either that the bodies which undergo such changes were

hydrets, or at least that hydrogen is the principle most easily acted on by the supporters of combustion.

M. Laurent has given us a theory of organic combinations, in some respects the same as that of Dumas; but more extended.* He considers the base or radical of every organic body to be a compound of carbon and hydrogen united together, so that the atoms of the carbon bear a simple relation to those of the hydrogen: the series which he gives are the following:—

Carbon,	1,	5,	2,	3,	5,	10
Hydrogen,	1,	2,	1,	2,	4,	7

In the first, the number of atoms of the carbon in the radical are equal to those of the hydrogen; in the second they are as 5 : 2; in the third as 2 : 1; in the fourth as 3 : 2; in the fifth as 5 : 4; and in the sixth as 10 : 7.

When these radicals are subjected to a dehydrogenizing process, as by passing a current of chlorine through them, they gradually lose their hydrogen or a part of it, but gain as many atoms of the dehydrogenizing body as they lose of hydrogen. So that if we add the number of atoms of the new body to those of hydrogen remaining the sum will make up the number of atoms of hydrogen originally present in the radical.

The dehydrogenizing body, or a part of it, being converted into water, nitric acid, muriatic acid, &c., may either be disengaged or remain combined with the new compound formed.

The fundamental radical and its derivatives will be neutral or alkaline, whatever be the portion of oxygen, hydrogen, chlorine, &c., entering into it. But when the oxygen, &c., enters into combination with the radical, it renders it *acid*, how small soever the uniting portion may be.

Those bodies which enter into combination without being a part of the radical, may be removed by heat, alkalies, &c., without being replaced by any thing else. But when a body constitutes a part of the radical, this cannot be done.

These are the most important points in M. Laurent's theory. It is not possible to illustrate it by examples, without entering into discussions which would lead us too far.

* Ann. de Chim. et de Phys. lxi. 128.

DIVISION I.

OF VEGETABLE PRINCIPLES.

It will be sufficient in the present state of our knowledge, to arrange those which are very numerous, under the four following classes:

1 Acids,
2 Alkalies,
3 Intermediate bodies,
4 Neutral bodies,

These will be described in succession under their respective heads.

CLASS I.

OF VEGETABLE ACIDS.

A considerable number of the acids belonging to the vegetable kingdom, were described in the *Chemistry of Inorganic bodies*, (vol. ii. p. 45). But so much has been done on this subject since the year 1831, when that work was published, that it will be necessary to resume the account of them here, referring to the former work for every thing which does not require to be corrected or amended.

The acids derived from the vegetable kingdom which have been recognised by modern chemists, and more or less accurately examined, amount to about 116. These acids are all composed of 2, 3, 4 or more constituents; two of them contain only carbon and oxygen; namely,

	Composition.
Oxalic, . .	$C^2\ O^3$
Croconic, . .	$C^5\ O^4$

Fifty-seven of them are composed of carbon, hydrogen, and oxygen.

One is composed of carbon, hydrogen, and azote; namely, Azulmic, $C^5\ H\ Az^2$

Two are composed of carbon, azote, and oxygen, namely,

Indigotic, . .	$C^8\ Az^3\ O^5$
Carbazotic, . .	$C^{15}\ Az^3\ O^{15}$

Five are composed of carbon, hydrogen, azote, and oxygen. There are 16 which, not having been hitherto subjected to chemical analysis, cannot be accurately classified. And, finally, there are 23 acids, which consist of combinations of some other powerful acid, sulphuric acid for example, with alcohol, ether, or some other vegetable principle.

In describing these acids, it will be convenient to divide them into sets. Perhaps the following subdivisions into 7 sets may answer our purpose.

1. *Volatile Acids* or acids which may be volatilized without decomposition. They are 17 in number.

2. *Fixed Acids* or acids that cannot be volatilized or distilled over

without decomposition. They are 34 in number. They consist of two divisions. The first are fixed acids, which, when exposed to heat, are decomposed, but furnish at the same time other acids which have been distinguished by the name *pyracids*. These are 8 in number; and the pyracids which they furnish amount to 14.

The second division consists of fixed acids whose pyracids are unknown.

4. *Oily acids*, or those acids into which oils or wax are converted when boiled with potash or soda. The combination of these acids with the alkali constitutes soap. They are 19 in number.

5. Acids containing *azote*. They are 8 in number.

6. *Acids* imperfectly examined. They are 16 in number.

7. *Compound* acids, consisting of a vegetable principle united to a strong mineral or vegetable acid. They are 23 in number.

Let us consider these different orders of acids in succession.

CHAPTER I.

VOLATILE ACIDS.

It has been already stated, that these acids, so far as our present knowledge extends, are 16 in number. The following table exhibits their names and atomic constitution, so far as it has been investigated.

		Constituents.
1	Oxalic,	C^2 O^3
2	Croconic,	C^5 O^4
3	Formic,	C^2 H O^3
4	Mellitic,	C^4 H O^4
5	Succinic,	C^4 H^2 O^3
6	Acetic,	C^4 H^3 O^3
7	Lactic,	C^6 H^4 O^4
8	Suberic,	C^8 H^6 O^3
9	Naphthalic,	C^{10} H^2 O^4
10	Sebacic,	C^{10} H^8 O^3
11	Camphoric,	C^{10} H^7 O^3
12	Valerianic,	C^{10} H^9 O^3
13	Benzoic,	C^{14} H^5 O^3
14	Cinnamonic,	C^{18} H^7 O^3
15	Hippuric,	C^{18} H^8 O^5 Az
16	Esculic,	C^{52} H^{46} O^{24}

SECTION I.—OF OXALIC ACID.

This acid has been described in detail, in the *Chemistry of Inorganic Bodies*, (vol. ii. p. 15). We shall here add the facts respecting it, which have been ascertained since that work appeared.

Though it contains only a single base, being composed of two

atoms carbon and three atoms oxygen, yet as it is so easily formed by the action of nitric acid upon a variety of vegetable substances, we may, without any great breach of propriety, introduce it here in order to point out what happens when it is exposed to determinate degrees of heat.

1. It was observed by Dobereiner that when the crystals of oxalic acid are heated in contact with sulphuric acid, they are resolved into equal volumes of carbonic acid and carbonic oxide. The water of the crystals in this case combines with the sulphuric acid, and the other constituents resolve themselves into the two gases just mentioned.* This experiment which has been frequently verified, demonstrates the composition of anhydrous oxalic acid. For

1 volume carbonic acid is . . .	$C\ O^2$
1 volume carbonic oxide is . . .	$C\ O$
Hence oxalic acid is . . .	$C^2\ O^3$

2. Gay-Lussac has made some important experiments on the decomposition of oxalic acid by the naked fire in a glass retort.† When the crystals are heated to 208° they fuse into a liquid. At 230° a gas is disengaged along with the vapour of water, and the quantity of this gas increases progressively in proportion as the temperature of the acid is elevated by the loss of its water of crystallization. Between 248° and 266° the disengagement was very rapid, and it continued till the complete decomposition of the acid with some variations of temperature, which were not exactly marked. If the heat be raised slowly, the whole acid is decomposed. The gas obtained is a mixture of

6 volumes carbonic acid,
5 volumes carbonic oxide.

The water distilled over was acid, and owed its acidity to the presence of a quantity of formic acid, formed during the decomposition of the oxalic acid.

Now it is easy from the known constitution of oxalic acid and formic acid to explain what happens during this decomposition. Let us suppose 12 atoms of oxalic acid crystals put into the retort, they are composed 12 atoms anhydrous oxalic acid, 36 atoms water, they yield

12 volumes carbonic acid . . .	$C^{12}\ O^{24}$
10 volumes carbonic oxide . .	$C^{10}\ O^{10}$
	$C^{22}\ O^{34}$
12 atoms of oxalic acid . . .	$C^{24}\ O^{36}$
Excess	$C^2\ O^2$

But an atom of formic acid is composed of $C^2\ H\ O^3$.

Let us suppose that one of the 36 atoms of water is decomposed and enters into the composition of the formic acid. Water is com-

* Schweigger's Journal für Chemie und Physik, xxiii, 66.
† Ann. de Chim. et de Phys. xlvi. 218.

posed of H O. If we add this to the excess in the oxalic acid over the carbonic acid, and carbonic oxide formed, we have C^2 H O^3, which is an atom of formic acid. Thus, it appears that by the action of heat on 12 atoms of oxalic acid, or 94·5 grains, we obtain

	Grains.
12 volumes carbonic acid . .	=33
10 volumes carbonic oxide . .	=17·5
1 atom formic acid . . .	= 4·625
35 atoms water	=39·375
	94·5

3. M. Dumas has obtained, by distilling oxalate of ammonia, a substance to which he has given the name of *oxamide*.* It will be described in a subsequent Chapter of this volume.

SECTION II.—OF CROCONIC ACID.

This acid has been described in the *Chemistry of Inorganic Bodies*, (vol. ii. p. 97). It is there stated, on the authority of L. Gmelin, that it is a compound of C^5 H O^4. But it is obvious that a mistake has been committed in the calculation. Gmelin obtained

Carbon	23·80
Hydrogen	0·15
Oxygen	25·54

Now this is equivalent to

5 atoms carbon . .	= 3·75
0·18 atoms hydrogen . .	= 0·0225
4 atoms oxygen . .	= 4

It is obvious that the hydrogen is too small, to constitute a true constituent. It must have been derived from a little water hygrometrically present, in the salt analyzed by Gmelin. This opinion I stated in the work referred to. It is at present generally adopted by chemists.

Liebig,† found that 100 parts of croconate of potash, when properly dried, yielded, when decomposed by oxide of copper, only 1·08 of water equivalent to $\frac{12}{10000}$ths of its weight of hydrogen. A quantity still smaller than that found by Gmelin, and inconsistent with the notion that hydrogen enters as a constituent into croconic acid. Liebig's analysis of this acid corresponds with that just stated.

SECTION III.—OF FORMIC ACID.

This acid is described in the *Chemistry of Inorganic Bodies*, (vol. ii. p. 58).

Dobereiner has pointed out an economical method of preparing this important acid, which deserves to be stated. It is as follows:—

Dissolve one part of sugar, starch, &c., in two parts of water, and

* An abreviation of *oxalic acid* and *ammonia*, because the substance in question is obtained from these two bodies conjointly.

† Ann. der Pharm. xi. 185.

mix the solution (in a large vessel) with $2\frac{1}{2}$ or 3 parts of binoxide of manganese in fine powder. This mixture is to be heated to 140°, and then 3 parts of concentrated sulphuric acid, previously diluted with its own weight of water, is to be added by little and little at a time, carefully agitating the mixture after every addition with a wooden rod. After the addition of the first third of the acid, so violent an effervescence takes place, that unless the vessel be at least 15 times the bulk of the mixture, a portion will run over. The effervescence is owing to the rapid formation and evolution of carbonic acid. At the same time, pungent vapours of formic acid are exhaled. To preserve these the mixture should be made in a copper alembic, the top of which should be put on and connected with the worm in the refrigeratory. When the violence of the effervescence is over, the rest of the sulphuric acid is to be added; the mixture is to be agitated, and the whole distilled over almost to dryness. A limpid acid liquid is obtained, having a strong smell, and consisting of water, formic acid, and an etherial liquor. Saturate the formic acid with carbonate of lime, and distil the liquor a second time to preserve the etherial liquid which comes over with the water, and from which it may be afterwards separated by distilling it off fused chloride of calcium.

A pound of sugar yields a quantity of formic acid, capable of saturating 5 or 6 ounces of carbonate of lime. To obtain the formic acid in a concentrated state, evaporate the formate of lime to dryness, and mix 7 parts of this dry salt previously reduced to powder with 10 parts of concentrated sulphuric acid and 4 parts of water, and distil in a retort. The formic acid passes into the receiver. If we substitute 6 parts of alchohol for the 4 parts of water and distil, we obtain formic ether.*

Many other vegetable substances besides sugar yield formic acid when treated with binoxide of manganese and sulphuric acid. According to Dobereiner, salicin yields it in greater quantity than any other.† M. C. G. Gmelin obtained it in the same way from sugar of milk, starch, lignin, althea root, mucic acid, &c., and also from alcohol; but he could not succeed in forming any from acetic acid.‡ Pelouze has shown that it is formed when hydrocyanic acid comes in contact with muriatic acid, ammonia being formed at the same time.§

Professor Emmet of the University of Virginia, affirms that the binoxide of manganese is of no use in this process. His method is as follows:—

Mix together in a retort equal measures of water, strong sulphuric acid, and clean, but unground, rye, maize, or any other grain. Heat to the boiling point, and as soon as the mass has become thoroughly blackened, add another measure of water, and distil off one measure of formic acid.‖

* Ann. de Chim. et de Phys. lii. 108. † Ibid, p. 110.
‡ Poggendorf's Annalen, xvi. 55. § Ann. de Chim. et de Phys. xlviii. 395.
‖ Silliman's Jour. xxxii. 140.

Dobereiner has pointed out a striking character of formic acid, by which its presence may be easily ascertained. When formic acid or formate of soda is put into a solution of any salt of gold, platinum, or silver, an effervescence takes place, carbonic acid is given off, and the gold, platinum, or silver is deposited in the metallic state.* When we mix formate of soda with a solution of corrosive sublimate, calomel is precipitated. Advantage might readily be taken of this important property to separate gold, platinum, or silver from other metals with which they may be in combination. When formic acid is dropt into a solution of nitrate of lead, crystals of formate of lead in needles are immediately deposited.

Liebig has found that formic acid may be obtained, containing only 1 atom water, by decomposing dry formate of lead by sulphuretted hydrogen. When of this strength it is much more corrosive than concentrated sulphuric acid. The smallest drop applied to the skin occasions a sensation, like that produced by red hot iron. A sore is produced, which is long in healing. This hydrate crystallizes at 32° and boils at 212° like water. The common acid, which is a bihydrate, crystallizes at 5° and boils at 226½°.†

SECTION IV.—OF MELLITIC ACID.

This acid has been described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 62). In that description an analysis of mellate of alumina by Wöhler is given. From this analysis it was inferred, that the atomic weight of mellitic acid is 6·5, and from the characters of the acid it was presumed that it contained no hydrogen; but was a compound of C^4 O^3.

But the subject has been lately investigated by Liebig and Pelouze.‡ They consider mellitic acid as a compound of

4 atoms carbon	3
4 atoms oxygen	4
1 atom hydrogen	0·125
	7·125

They consider the atom of water which may be extricated from the acid, not as existing in it as water, but as constituting an integrant part of the acid. They found that 100 parts of mellate of silver dried for 24 hours over sulphuric acid *in vacuo*, were composed of

Mellitic acid,	33·08 or	7·167
Oxide of silver	66·92 or	14.5

This raises the atomic weight to 7·167.

The salt thus dried loses no more weight though kept at 212°. But at a higher temperature, water is again disengaged. After this, if it be heated up to 356° it loses its white colour, and assumes that of chloride of silver. When the heat is still farther raised, a slight detonation is observed, and there remains what is probably a chemical compound of carbon and silver, but no water whatever is extri-

* Ann. de Chim. et de Phys. lii. 107 † Jour. de Pharmacie, xxi. 381.
‡ Ann. der Pharm. xix. 252.

cated. The mellate of silver, dried *in vacuo*, contains mellitic acid, composed of C^4 H O^4, and an atom of oxide of silver: that dried in a higher temperature, is C^4 O^4 Ar. Liebig and Pelouze are of opinion, that the atom of hydrogen in the acid, combines with the oxygen of the base, and thus reduces the silver to the metallic state.

SECT. V.—OF SUCCINIC ACID.

This has been described in the *Chemistry of Inorganic Bodies*, (vol. ii. p. 89). It has been recently analyzed by MM. Liebig and Wöhler,* and by M. Felix Darcet.† The results obtained agree with the old analysis by Berzelius, given in the *Chemistry of Inorganic Bodies*, (ii. 91). But a number of important facts respecting this acid has been ascertained by M. F. Darcet, which it will be proper to state here.

Succinic acid may be obtained in three states:—1. Combined with an atom of water. 2. Combined with half an atom of water. 3. Anhydrous.

In the first state it constitutes the crystallized acid of the shops, supposing that acid pure. It is soluble in water, and much more soluble in hot than in cold water. So that it is easily crystallized by cooling the hot solution. It is less soluble in alcohol, and scarcely at all in ether. It melts at 356° and boils at 455°.

To determine the atomic weight of succinic acid, Darcet analyzed anhydrous succinate of silver, and obtained

Succinic acid . . .	30·39 or 6·33
Oxide of silver . . .	69·61 or 14·5
	100·00

According to this analysis the atomic weight of succinic acid is 6·33, approaching as nearly to 6·25, which I had shown to be its true atomic weight, as could be expected. M. Darcet‡ analyzed the crystallized succinic acid by means of oxide of copper, and obtained, as the ultimate constituents,

Carbon	40·22 or 4 atoms=3	or per cent.	40·67
Hydrogen	5·48 or 3 atoms=0·375	— —	5·09
Oxygen	54·30 or 4 atoms=4	— —	54·24
	100 7·375		100

These numbers correspond with an atomic weight of 7·375, while dry succinic acid has an atomic weight of 6·25, and is composed of C^4 H^2 O^3. It is obvious that the crystals consist of an atom of succinic acid combined with an atom of water; or it is C^4 H^2 O^3 + H O.§

When crystallized succinic acid is kept for a long time in a retort at a temperature of 266° or between that and 284°, it under-

* Poggendorf's Annalen, xviii. 163.
† Ann. de Chim. et de Phys. lviii. 282.
‡ Journ. für Pract. ch. iii. 212, or Jour. de Pharmacie, xx. 656.
§ This new analysis corresponds sufficiently with the old one by Berzelius.

goes a remarkable change. By degrees there are deposited, in the neck of the retort, a great number of beautiful white needles, while at the same time a little water is disengaged. These needles consist of succinic acid deprived of half its water, while the portion in the retort remains unaltered. It seems to have been this dihydrous succinic acid that was analyzed by Liebig and Wöhler. M. Darcet subjected it to analysis and obtained

Carbon	43·46 or 4	atoms=3	or per cent.		44·03
Hydrogen	4·87 or $2\frac{1}{2}$	atoms=0·3125	—	—	4·59
Oxygen	51·67 or $3\frac{1}{2}$	atoms=3·5	—	—	51·38
		6.8125			100

Liebig and Wöhler obtained

Carbon	44·12
Hydrogen	4·83
Oxygen	51·05
	100·00

These numbers correspond, as nearly as could be expected, with the supposition, that the needles consist of an atom of succinic acid united to half an atom of water.

Anhydrous succinic acid may be obtained by distilling a mixture of dry phosphoric acid with crystallized succinic acid. The best method of proceeding is, to fuse the succinic acid in a retort, and then add the phosphoric acid and distil slowly. We obtain in the receiver a crystalline mass, white, and consisting of anhydrous succinic acid. It yielded when analyzed,

Carbon	47·34 or 4	atoms=3	or per cent.		48
Hydrogen	4·20 or 2	atoms=0·25	—	—	4
Oxygen	48·46 or 3	atoms=3	—	—	48
	100·00	6·25			100

Thus we see that the atomic weight of anhydrous succinic acid is 6·25

Anhydrous succinic acid, though left exposed to the air, does not recover the water which it has lost. It melts, when heated to 393°, and boils at the temperature of 482°.

It is less soluble in water than hydrous succinic acid; but more soluble in alcohol and ether. If we dissolve it in water and crystallize, we shall find that the crystals recover the atom of water which the acid had lost. The salts formed by it are the same as those formed with crystallized succinic acid.

SECTION VI.—OF ACETIC ACID.

The only addition which it seems necessary to make to the account of acetic acid, given in the 2d volume of the *Chemistry of Inorganic Bodies*, is the following, for which we are indebted to M. Pelouze.

Liquid acetic acid, composed of 1 atom pure acid and 1 atom

water, which has a specific gravity of 1·06296, does not redden litmus paper. It may be kept in contact with dry carbonate of lime, as long as we please, or even boiled over it without disengaging a single bubble of carbonic acid gas, or combining with the lime; yet it dissolves quicklime instantly. It decomposes carbonate of potash, soda, lead, zinc, strontian, barytes, and magnesia, disengaging their carbonic acid; but its action on the last three carbonates is very slow. The same acid, when diluted with water, acts with great energy on all these carbonates. When the crystallizable acetic acid is mixed with several times its volume of alcohol, it loses all its action upon every one of these carbonates.

If we dissolve acetate of potash in alcohol, and pass a current of carbonic acid gas through the solution, carbonate of potash is precipitated and acetic ether formed. But carbonic acid does not throw down lime from the acetate dissolved in water.*

SECTION VII.—OF LACTIC ACID.

The account of lactic acid, in the *Chemistry of Inorganic Bodies*, (ii. 55), left some uncertainty about its nature, which has been removed by the subsequent experiments of MM. Jules Gay-Lussac and Pelouze.†

These chemists obtained pure lactic acid by the following process. A large quantity of beet-root juice was placed in a stove, and kept at a temperature between 77° and 86°. In a few days, fermentation commenced, and hydrogen and carburetted hydrogen gases were disengaged in abundance. When this fermentation (which continued about two months) had subsided, the liquid was evaporated to the consistence of a syrup. Crystals of mannite made their appearance in it, and it contained a quantity of sugar similar to that from the sugar cane. The syrup being digested with alcohol, the lactic acid was dissolved in that liquid, while various substances, not subjected to examination, were left undissolved. Water was mixed with the alcoholic solution, and the alcohol distilled off, which occasioned another precipitation. The lactic acid in the aqueous solution, was saturated with carbonate of zinc. This saturation occasioned a still more abundant precipitation than had taken place before. The liquid being sufficiently concentrated, the lactate of zinc crystallized. It was collected and heated in water, containing animal charcoal previously digested in muriatic acid. The boiling solution being filtered and concentrated, lactate of zinc separated in crystals perfectly white. They were washed in boiling alcohol, in which liquid they are insoluble. The lactate of zinc thus purified, was dissolved in water, and the oxide of zinc precipitated by barytes water. The lactate of barytes thus formed, was decomposed, by adding just the quantity of sulphuric acid requisite to saturate the barytes contained in it. The liquid was filtered, and

* Pelouze, Ann. de Chim. et de Phys. l. 314.
† Ann. de Chim. et de Phys. lii. 410.

the lactic acid concentrated by evaporation, in the vacuum of an air-pump. Finally, the lactic acid thus obtained in a state of dryness, was agitated with sulphuric ether, which dissolved it, leaving behind a few particles of a flocky matter.

Lactic acid obtained in this way, and as concentrated as possible, is a colourless liquid, of a syrupy consistence, and having a specific gravity (at the temperature of 69°) of 1·215. It has no smell. Its taste is exceedingly sour. Indeed, in this respect it may be compared to the most powerful of the vegetable acids. It attracts moisture when exposed to the air. Water and alcohol dissolve it in all proportions, ether likewise dissolves it, but in smaller quantity.

When boiled with concentrated nitric acid, it is converted into oxalic acid.

Two drops of lactic acid, added to 1543 grains of boiling milk, produce its immediate coagulation. But a considerably greater quantity of the acid does not alter cold milk. It possesses also the property of coagulating albumen when added in small quantity.

It dissolves the phosphate of lime of bones with rapidity.

When boiled with a solution of acetate of potash, it disengages the acetic acid.

When dropt into a concentrated solution of acetate of magnesia, it occasions in a few minutes a white granular precipitate of lactate of magnesia, and the liquid assumes a strong smell of vinegar. It throws down in like manner a precipitate of lactate of zinc, when added to a concentrated solution of acetate of zinc. But lactate of silver is decomposed by acetate of potash, acetate of silver being deposited in abundance.

Lactic acid occasions no muddiness in lime, strontian, or barytes water.

When lactic acid in its most concentrated state is heated gradually, and cautiously, it becomes more fluid, assumes a darker colour, and gives (besides inflammable gas, vinegar, and a residue of charcoal) a great quantity of white solid matter, having at once an acid and bitter taste. When this substance is exposed to pressure between folds of blotting paper, it is freed from an odorous substance which accompanies it. Thus purified, it dissolves abundantly in boiling alcohol, whence it is deposited, as the solution cools in very white rhomboidal tables. These crystals have no smell, and their taste is incomparably less sour, than that of the lactic acid in a liquid state, owing doubtless to their little solubility in water. These crystals melt when heated to 125°. They boil at the temperature of 482°, giving out white and irritating vapours. When these vapours are brought in contact with a cold body, they form crystals similar to those from which they were produced. These vapours are inflammable, and burn with a pure blue flame. The crystals may be sublimed, without leaving any residue, and give no indication of the presence of water. Its tendency to assume a crystalline form is very remarkable.

These crystals dissolve very slowly in water; but the solution

once formed cannot be made to yield crystals. It thickens to a syrup, and presents exactly the appearance and properties of the liquid lactic acid, from which they were originally obtained.

MM. Jules Gay-Lussac and Pelouze, subjected the syrupy acid to analysis, and obtained from an average of two trials,

Carbon	40·30 or 6 atoms	=4·5	or per cent.	40
Hydrogen	6·96 or 6 atoms	=0·75	—	—	6·66
Oxygen	52·74 or 6 atoms	=6	—	—	53·34
	100·00	11·25		100

The crystals being analyzed in the same way, gave, as the average of three trials,

Carbon	49·1 or 6 atoms	=4·5	or per cent.	50
Hydrogen	5·6 or 4 atoms	=0·5	—	—	5·5
Oxygen	45·3 or 4 atoms	=4	—	—	44·5
	100·0	9		100·0

MM. Jules Gay-Lussac and Pelouze analyzed lactates of zinc, copper, and silver, and the mean of four analyses gives the atomic weight of lactic acid 10·33. Now,

6 atoms carbon . .	= 4·5
5 atoms hydrogen . .	= 0·625
5 atoms oxygen . .	= 5·0
	10·125

But the analysis of lactic acid gave only 6 atoms carbon, 4 atoms hydrogen, and 4 atoms oxygen. Hence it would appear, that the lactates examined, after being dried at 248°, still retain an atom of water. The true atomic weight of anhydrous lactic acid is doubtless 9, and it differs from acetic acid, by containing 2 additional atoms of carbon + 1 atom hydrogen + 1 atom oxygen.

This analysis of lactic acid, has been confirmed by MM. Liebig and E. Mitscherlich,* they found that lactate of zinc was composed of

Lactic acid	54·93 or	10.316	=1 atom
Oxide of zinc	27·29 or	5·125	=1 atom
Water	17·78 or	3·375	=3 atoms
	100·00		

The salt had been kept at 266° till it ceased to lose water.

Their analysis of the acid in the salt, gave the formula

6 carbon,	=4·5	or per cent.	44·44
5 hydrogen,	=0·625	—	—	6·17
5 oxygen,	=5	—	—	49·39
	10·125		100

If we admit that the acid, after exposure to a heat of 266°, stil

* Annalen der Pharm. vii. 47.

retained an atom of water, the result obtained by Liebig and Mitscherlich, will coincide with that of J. Gay-Lussac and Pelouze.

Liebig has shown that the acid in *sauer kraut* is the lactic.*

We are indebted to J. Gay-Lussac and Pelouze for an examination of several of the lactates, with an account of which we shall terminate this section.

1. *Lactate of lime.* This salt is white and very soluble in boiling water, from which it is deposited, on cooling, in very short white needles, radiating from a common centre. It is very soluble in hot alcohol. When heated it undergoes the watery fusion, and afterwards the igneous fusion, and is at last decomposed like other salts containing a combustible acid. Its constituents are

1 atom lactic acid	9
1 atom lime	3·5
6 atoms water	6·75
	19·25

2. *Lactate of magnesia* is easily obtained by double decomposition. It forms brilliant white crystals, which effloresce slightly in the air, and require 30 times their weight of water to dissolve them. They are composed of

1 atom lactic acid	9
1 atom magnesia	2·5
4 atoms water	4·5
	16

3. *Lactate of alumina* crystallizes, though with difficulty. It is very soluble in water. The same description applies to the *lactates of potash*, *soda* and *ammonia*.

4. *Lactate of protoxide of iron.* Lactic acid attacks iron filings with energy, while hydrogen gas is evolved. The lactated protoxide of iron precipitates in four-sided needles, little soluble in water and exceedingly white. In a dry state it does not alter by exposure to the air; but when held in solution by water, the iron is speedily peroxidized. Its constituents are

1 atom lactic acid	9
1 atom protoxide of iron . . .	4·5
6 atoms water	6·75
	20·25

5. *Lactate of peroxide of iron* is brown and deliquescent.

6. *Lactate of manganese* crystallizes readily. The shape, according to M. Braconnot, is a flat rectangular prism terminated by a bihedral summit.

7. *Lactate of cobalt* has a red colour, and crystallizes in grains little soluble in water. It is composed of

* Ann. der Pharm. xxiii. 113.

1 atom lactic acid	9
1 atom oxide of cobalt	4·25
3.5 atoms water	3·9375
	17·1875

When the water is driven off it assumes an exceedingly beautiful colour.

8. *Lactate of nickel* has a grass-green colour, and is more soluble than lactate of cobalt. Its crystals were so confused that the shape could not be determined.

9. *Lactate of zinc* is white, and little soluble in cold, but more soluble in boiling water. It crystallizes in four-sided prisms terminated by oblique summits. It is insoluble in alcohol, and is composed of

1 atom lactic acid	9
1 atom oxide of zinc	5·125
4 atoms water	4·5
	18·625

10. *Lactate of copper* has a fine blue colour and crystallizes readily in four-sided prisms. It effloresces when exposed to the air. It is insoluble in alcohol. It may be formed by leaving lactic acid in contact with suboxide of copper. Lactate is formed and copper separates. This salt is composed of

1 atom lactic acid	9
1 atom oxide of copper	5
3 atoms water	3·375
	17·375

11. *Lactate of mercury* is very soluble in water, and on that account is not easily crystallized.

12. *Lactate of silver* crystallizes in fine but long needles. It is very white, very soluble in water, and easily altered by light.

13. *Lactate of chromium* does not crystallize.*

SECTION VIII.—SUBERIC ACID.

In the history of this acid, in the *Chemistry of Inorganic Bodies* (ii. 117), the constituents of it, according to the analysis of it by Dr R. Brandes, are given as follows:—

Carbon	37·2536
Hydrogen	15·9856
Oxygen	46·7608
	100·0000

M. Bussy had analysed it in 1822, and had obtained

Carbon	56·29
Hydrogen	6·89
Oxygen	36·82
	100·00†

* Ann. de Chim. et de Phys. lii. 410. † Jour. de Pharmacie, viii. 110.

The great difference between this result and that of Brandes, induced him to repeat his analysis.

The acid employed was carefully prepared, and seems to have been ultimately sublimed, in order to free it completely from all foreign matter. It was white, quite soluble in water, and had a weak acid taste. It did not melt till it was heated to 255°. If it be dried at 212°, it loses no weight when fused. When the heat is raised above 255°, suberic acid distils over like the *fat acids*. If the acid was not quite pure, but had a yellow colour, the first portion distilled was a dirty rose red, the middle portions were pure, and the last portion impure and yellow. When the acid was pure, what came over was pure, and on cooling, concreted into a crystalline mass, having a slightly empyreumatic smell; and there remained in the retort a small quantity of charry matter. It was soluble in water and alcohol, and precipitated from alcohol by water.

M. Bussy found suberate of lead rendered anhydrous, to be composed of

Suberic acid . . .	207·6 or 9·905
Oxide of lead . .	292·4 or 14
	500·0

According to this analysis, the atomic weight of suberic acid is 9·905.

The sublimed acid being analysed by means of oxide of copper, the mean of five analyses gave

Carbon	55·20 or 8 atoms	= 6	or per cent.	55·18
Hydrogen	8·03 or 7 atoms	= 0·875	— —	8·04
Oxygen	36·77 or 4 atoms	= 4	— —	36·78
	100	10·875		100

But when 100 parts of sublimed suberic acid are heated with oxide of lead, they lose, at an average of three experiments, 9·133 of their weight, showing that water is still present. It is obvious from this, that the sublimed acid contains 1 atom of water. The anhydrous acid, of course, is a compound of

8 atoms carbon . .	6
6 atoms hydrogen . .	0·75
3 atoms oxygen . .	3
	9·75

So that its true atomic weight is 9·75.*

SECTION IX.—OF NAPHTHALIC ACID.

This acid was discovered and described by M. Laurent, about the beginning of 1836.† The mode of preparing it is the following:

* Bussy, Poggendorf's Annalen, xxix. 151, and Jour. de Pharmacie, xix. 425. These experiments of Bussy were confirmed by the subsequent researches of Brandes. See Ann. der Pharmacie, ix. 295.

† Ann. de Chim. et de Phys. lxi. 113.

Introduce into a retort muriate of chloronaphthalese,* and pour on it four or five times its weight of common nitric acid, and raise the temperature to the boiling point. The action is very slow, about 300 grains of the matter requiring a whole day to convert it into naphthalic acid. Evaporate the solution to dryness to get rid of the greatest part of the nitric acid. We obtain a mass confusedly crystallized, and having a yellow colour. Pour into the retort a large quantity of water, and boil till the greater part of this residue is dissolved. A little brown matter remains, which is sometimes mixed with a small portion of muriate of chloronaphthalese unaltered. Filter the solution while boiling hot. On cooling, pearly plates are deposited, which commonly unite in concentric round groups. Decant off the mother water, and evaporate again. On cooling we get a new crop of crystals. And in this way we proceed till we exhaust the liquid.

Naphthalic acid thus obtained has a yellowish red colour. To purify it we must dissolve it anew, and crystallize it a second time, or it may be sublimed. For sublimation, it may be put into a porcelain capsule, covered with a glass capsule containing cold water. When the lower capsule is slightly heated the acid sublimes, and crystallizes on the glass capsule in the form of beautiful white needles, having a great deal of lustre.

The acid thus purified is white, brilliant, and in long feathery crystals. They are, in fact, oblique four-sided prisms. Naphthalic acid has a great deal of resemblance to benzoic. When heated it melts at 221°; on cooling, it concretes into a fibrous mass. When the heat is still farther raised, the acid is volatilized without decomposition in white fumes, which have a certain degree of pungency. These fumes readily catch fire and burn with a strong flame, giving out much soot.

Naphthalic acid is unaltered in the air. When kept in corked phials it is slightly volatilized, crystals being deposited on the sides of the phial at the end of some months. It has no smell. Its taste is weak, and by no means disagreeable.

While dry it has no effect on litmus paper; but it reddens it if moistened. In cold water it is scarcely soluble; but pretty soluble in boiling water. Alcohol and ether dissolve it easily. Chlorine has no action on it. Muriatic acid, nitric acid, and sulphuric acid, dissolve it at a boiling heat, but do not alter it.

M. Laurent analyzed it by means of oxide of copper, and obtained

Carbon	64·70 or	10 atoms	= 7·5	or per cent.	63·83
Hydrogen	2·38 or	2 atoms	= 0·25	— —	2·13
Oxygen	32·92 or	4 atoms	= 4·0	— —	34·04
	100		11·75		100

* For the nature of this body, see a subsequent Chapter, in which naphthaline and its compounds are described.

The acid, in the state in which it was analyzed, was anhydrous. But when it is crystallized from a solution in boiling water, it is combined with an atom of water.

The alkaline naphthalates are very soluble in water, and less soluble in alcohol. The naphthalates with bases of the alkaline earths, are little soluble. Those of lead and silver are insoluble; yet the water employed to wash them becomes muddy when mixed with muriatic or sulphuric acid.

The greater number of them have the singular property, when heated, of becoming elongated to a great extent under the form of a black glass, while, at the same time, a peculiar crystalline matter is disengaged from them. The soluble naphthalates, when in solution, may be recognised by mixing them with muriatic or nitric acid, a white precipitate falling crystallized in needles. It is naphthalic acid. If they are insoluble, we heat them in a tube with some drops of concentrated sulphuric acid: naphthalic acid sublimes in needles. Naphthalic acid is very similar in appearance to benzoic acid, but it may be easily distinguished by combining it with ammonia, with which it forms a very characteristic salt.

1. *Naphthalate of ammonia.* When we leave to spontaneous evaporation a solution of naphthalate of ammonia the base is disengaged by little and little, and we obtain an acid salt remarkable for the beauty of its crystallizations. The crystals are right oblique prisms, with a cleavage parallel to the rhombic bases. We may, by means of a knife, detach plates as thin as those of sulphate of lime. Sometimes the crystals are hexagonal plates, sometimes in octahedrons, obviously derived from the prism.

It is not altered by exposure to the air, and strongly reddens litmus paper. When heated in a tube it melts, and then is decomposed without leaving any residue; being converted into water, ammonia, and a new acid, which sublimes in white plates.

Its composition, as determined by the analysis of Laurent, is as follows:—

$1\frac{1}{3}$ atom naphthalic acid . .	15·66
1 atom ammonia . . .	2·125
$1\frac{1}{3}$ atom water	1·5
	19·285

No doubt, if it could be crystallized without loss of ammonia, the composition would be

1 atom naphthalic acid . .	11·75
1 atom ammonia . . .	2·125
2 atoms water	2·25
	16·125

Probably it might be obtained in this state by crystallizing *in vacuo* over sulphuric acid.

2. *Naphthalate of potash.* This salt is exceedingly soluble in water. To obtain it in crystals, we must evaporate the aqueous

solution to dryness, and dissolve the residue in ether. We obtain the salt in scales, having a pearly lustre. When dried, it is composed of

1 atom naphthalic acid . . .	11·75
1 atom potash	6
	17·75

3. *Naphthalate of soda.* It is also very soluble. When left to spontaneous crystallization the surface becomes covered with a crystalline crust, which prevents the rest of the liquid from evaporating. When dissolved in boiling alcohol it crystallizes in plates as the solution cools.

4. *Naphthalate of barytes.* Obtained by mixing concentrated solutions of naphthalate of ammonia and chloride of barium. It precipitates in white scales, soluble in water.

5. *Naphthalate of lime.* Similar to naphthalate of barytes, and obtained by the same kind of process.

6. *Naphthalate of magnesia.* Sulphate of magnesia is not precipitated by naphthalate of ammonia.

7. *Naphthalate of zinc.* This salt is little soluble in water. As we evaporate its solution it falls down in a crystalline powder. When heated it is decomposed, giving out an oil which crystallizes on cooling. It may be obtained by dissolving carbonate of zinc in naphthalic acid.

8. *Naphthalate of lead.* When boiling solutions of naphthalate of ammonia very dilute, and a salt of lead are mixed together, naphthalate of lead falls down in silver white plates. It constitutes a neutral salt.

9. *Naphthalate of silver.* Obtained by mixing boiling solutions of naphthalate of ammonia and nitrate of silver. The salt precipitates in white shining plates. When heated in a porcelain dish, it decomposes with such rapidity, that M. Laurent was not able to determine its composition exactly.

Naphthalamide.

This substance may be obtained by heating naphthalate of ammonia in a retort. Water and ammonia are disengaged, and naphthalamide sublimes, while nothing remains in the retort.

Naphthalamide is colourless, inodorous and insipid. When heated, it enters into fusion, and on cooling solidifies into a fibrous mass. When heated more strongly, it boils, emitting vapours which condense under the form of very light crystalline plates. It is almost insoluble in cold water. Boiling water dissolves a little, but as the liquid cools the naphthalamide is deposited in very fine silky needles.

Weak and dilute acids have no action on it. Chlorine does not attack it. Concentrated sulphuric acid dissolves it with the assistance of heat. If we dilute the solution with water and allow it to cool, crystals of hydrated naphthalic acid are deposited. A con-

centrated alcoholic solution of potash, when boiled upon it, disengages ammonia. If we now saturate the potash with sulphuric acid and evaporate to dryness, naphthalic acid sublimes.

M. Laurent subjected naphthalamide to an analysis by means of oxide of copper. He obtained

Carbon	64·65 or 33	atoms =	24·75	or per cent.	64·39
Hydrogen	3·10 or $9\frac{1}{2}$	atoms =	1·1875	— —	3·09
Azote	8·90 or 2	atoms =	3·50	— —	9·10
Oxygen	23·35 or 9	atoms =	9·00	— —	23·42
	100·00		38·4375		100

M. Laurent considers it as isomeric with binaphthalate of ammonia. But supposing we were to reduce the atoms to one-half, they would not tally with binaphthalate of ammonia, which is $C^{20}\ H^{4}\ O^{8} + H^{3}\ Az$; while naphthalamide would be $C^{16\frac{1}{2}}\ H^{11}\ O^{4\frac{1}{2}} + H^{3}\ Az$.

Naphthalic ether.

If we boil in a retort, a mixture of alcohol, muriatic acid, and naphthalic acid, we obtain at the end of the distillation an oily matter which remains in the retort. It is heavier than water, and is considered by M. Laurent, who, however, has never examined it, as naphthalic ether.

SECT. X.—OF SEBACIC ACID.

Though this acid had been noticed by the chemists of the last century, and though Crell had given various processes for preparing it;* yet its characters do not seem to have been determined till Thenard published an account of it in the year 1799.† Berzelius, in his *Traité de Chimie*, considers it as the same with benzoic acid; but the analysis of it in 1834, by Dumas and Peligot, showed that it had no resemblance whatever to that acid in its composition.‡

It is easily obtained by distilling a quantity of tallow, and agitating the product in boiling water, which dissolves the acetic acid. The water thus impregnated is mixed with acetate of lead, which throws down a precipitate of sebate of lead. It is washed, dried, and treated with dilute sulphuric acid, which forms an insoluble compound with the oxide of lead. The sebacic acid, thus set at liberty dissolves very well, if we boil it in water, and it crystallizes when the liquid cools. By two or three successive crystallizations it is freed from any sulphuric acid with which it may be at first mixed, and brought into a state of purity.

Sebacic acid thus obtained crystallizes in white needles, having a pearly lustre. It has no smell, and is almost destitute of taste, though it reddens litmus paper.

It melts when heated, and may be volatilized like benzoic acid, and

* Jour. de Phys. xviii. 100 and 383—xix. 384.
† Ann. de Chim. xxxix. 193.
‡ Ann. de Chim. et de Phys. lvii. 332.

is much more soluble in hot than in cold water. It is very soluble in alcohol. When a strong acid is poured into a concentrated sebate, a precipitate of sebacic acid immediately appears.

Dumas and Peligot subjected it to two several analyses by means of oxide of copper. The analyses do not agree very well with each other. But they seem to consider the last as the most to be depended on. Taking it as correct, the constituents of sebacic acid are

Carbon	59·59 or 10 atoms	=7·5	or per cent.	59·40
Hydrogen	9·04 or 9 atoms	=1·125	— —	8·91
Oxygen	31·37 or 4 atoms	=4	— —	31·69
	100·00	12·625		100·00

To determine the atomic weight of sebacic acid they dissolved in water a quantity of neutral sebate of ammonia, and mixed the solution with nitrate of silver. The sebate of silver which precipitated was well washed and dried at the temperature of 248° *in vacuo*. In two successive analyses they obtained

Sebacic acid	106·7 or 11·77
Oxide of silver . . .	131·3 or 14·5
Sebacic acid	91·2 or 11·93
Oxide of silver . . .	110·8 or 14·5

The mean of these analyses gives us 11·85 for the atomic weight of sebacic acid. But the atomic weight deduced from the analysis of the acid is 12·625 greater than results from the constitution of sebate of silver. It is obvious from this, that the sebacic acid, as it was analyzed by Dumas and Peligot, was a hydrate containing one atom of water. If we subtract this atom, we have for the composition of anhydrous sebacic acid,

10 atoms carbon	=7.5
8 atoms hydrogen	=1
3 atoms oxygen	=3
	11·5

giving us an atomic weight of 11·5, which does not deviate too far from that deduced from the sebate of silver.

Now this constitution is quite different from that of benzoic acid which is composed of

14 atoms carbon	=10·5
5 atoms hydrogen	= 0·625
3 atoms oxygen	= 3·0
	14·125

And has an atomic weight of 14·125.

Sebacic acid occasions precipitates when dropt into acetate or nitrate of lead, nitrate of silver, acetate or nitrate of mercury. It saturates the alkalies and forms with them soluble salts.

The sebate of potash does not absorb moisture from the air, it has little taste, and when sulphuric, nitric, or muriatic acid is added to it, the solution becomes muddy, and sebacic acid is deposited.

It produces no precipitates when dropt into lime, barytes, or strontian water.

SECT XI.—OF CAMPHORIC ACID.

This acid has been described in the *Chemistry of Inorganic Bodies*, (vol. ii. p. 114). But since that time an important set of experiments on its composition, and that of camphor, has been made by M. Liebig.*

When camphor is treated with concentrated nitric acid, it melts, as is well known, into a yellowish liquid. If we prolong the digestion this yellow liquid disappears entirely, and the acid on cooling deposits a great number of white opaque crystals, which, when boiled with water, communicate to its vapour the odour of camphor. These crystals constitute the *camphoric acid* of Bouillon La Grange, which form, with all the bases, salts which are insoluble or nearly so. They are in reality a chemical combination of camphoric acid and camphor, and may be formed directly by dissolving camphor in camphoric acid melted in a gentle heat. If we treat these crystals a second time with concentrated nitric acid, we obtain more transparent crystals. These crystals constitute *camphoric acid*, and form the same kind of salts which Brandes described. An account of them will be found in the Chapter on Salts, in the second volume of the *Chemistry of Inorganic Bodies.*

To determine the atomic weight of this acid, Liebig combined it with oxide of lead and tried experimentally how much sulphate of lead a given weight of the anhydrous camphorate of lead was capable of furnishing. The result was that the salt is composed of

Camphoric acid	957 or 14
Oxide of lead	957 or 14
	1914

This gives 14 for the atomic weight of camphoric acid. Liebig subjected camphoric acid to an analysis by means of oxide of copper, and obtained

Carbon	61·4098 or	12 atoms=9	or per cent.	64·28
Hydrogen	6·8070 or	8 atoms=1	— —	7·14
Oxygen	31·7832 or	4 atoms=4	— —	28·58
	100	14		100·00

But these numbers differ so much from the results obtained, that the analysis cannot be considered as satisfactory. This induced M. Liebig to heat a portion of his camphoric acid a third time with nitric acid, and to continue the action till all smell of camphor disappeared, when the camphoric acid was boiled with water. Camphorate of lead prepared with this new acid was composed of

Camphoric acid . . .	545 or 13·625
Oxide of lead . . .	560 or 14
	1105

* Ann. de Chim. et de Phys. xlvii. 95.

According to this new analysis the atomic weight is only 13·625 instead of 14, as by the first analysis. The camphorate of lead being analyzed by means of oxide of copper, he obtained

Carbon	56·167 or 10	atoms=	7·5	or per cent.	55·82
Hydrogen	6·981 or 7½	atoms=	0·9375	— —	6·97
Oxygen	36·852 or 5	atoms=	5	— —	37·21
	100		13·4375		100·00

This would make the atomic weight 13·4375, which differs but little from that obtained from the analysis of camphorate of lead.

When camphor is treated with nitric acid, no effervescence or disengagement of carbonic acid is observed. From this it would seem, that camphor constitutes the base of camphoric acid, or that camphoric acid is a compound of camphor and oxygen. To determine this point, M. Liebig analyzed camphor, and obtained

Carbon . . .	81·763
Hydrogen . . .	9·702
Oxygen . . .	8·535
	100·000

These numbers lead to the conclusion that camphor is a compound of

81·763 or 12 atoms carbon		=	9	or per cent.	80·89
9·702 or 9 atoms hydrogen		=	1·125	— —	10·12
8·535 or 1 atom oxygen		=	1·	— —	8·99
100			11·125		00·00

or 6 (C^2 $H^{1\frac{1}{8}}$) + O.

Now, if we express the composition of camphoric acid by the formula 5 (C^2 $H^{1\frac{1}{8}}$) + O^5, it will result from camphor, if each of the atoms of camphor combine with 5 atoms of oxygen. So that 5 atoms of camphor will produce 6 atoms of camphoric acid. This explanation, for which we are indebted to Liebig, seems a little strained. It would be simpler to consider camphor as composed of C^{10} $H^{7\frac{1}{2}}$ O, and to admit that it is converted into camphoric acid, merely by combining with 4 atoms of oxygen. This would make the constitution of camphor

Carbon	79·55
Hydrogen	9·93
Oxygen	10·52
	100·00

Now, if we consider the great difficulty of analyzing camphor with accuracy, perhaps the deviation of these numbers from those obtained by Liebig, is not greater than might have been expected.

M. Laurent has made a set of experiments still more lately on the component parts of camphoric acid. To convert the camphor into camphoric acid, he distilled it 30 times in succession with nitric acid.

From the analysis of camphorate of silver, he deduced the atomic weight of the acid to be 11·7. The anhydrous acid he found composed of

10 atoms carbon	= 7·5	or per cent.	65·93
7 atoms hydrogen	= 0·885	— —	7·69
3 atoms oxygen	= 3·	— —	26·38
	11·385		100·00

The hydrous acid of

10 atoms carbon	= 7·5	or per cent.	60
8 atoms hydrogen	= 1·	— —	8
4 atoms oxygen	= 4·	— —	32
	12·5*		100

Still more lately M. Mallagutti has repeated this analysis with crystallized acid, and obtained

Carbon	59·50
Hydrogen	7.98
Oxygen	33·52
	100·00†

These numbers correspond with the following atomic constitutions:—

10 atoms carbon	= 7·5	or per cent.	60
8 atoms hydrogen	= 1	— —	8
4 atoms oxygen	= 4	— —	32
	12·5		100

If we consider this acid as containing an atom of water, of course, the anhydrous acid will have the constitution assigned above by M. Laurent.

The coincidence in the results of these two chemists, seems to leave no doubt about the true constitution of camphoric acid.

SECTION XII.—OF VALERIANIC ACID.

Some years ago, M. Pentz accidentally discovered an acid in the water expressed from the *valeriana officinalis*. From some experiments which he made on this acid, he considered it to be the acetic. M. Grote made some additional experiments on this acid, but did not determine whether it was merely acetic acid, or an acid of a different nature. In 1833, M. J. Trommsdorf published the result of his experiments upon it, described its properties, and showed that it differed in its characters from all the acids hitherto observed, and that it was entitled to rank as a peculiar acid. He gave it the name of valerianic acid, from the plant from which alone it can be procured.‡

* Ann. de Chim. et de Phys. lxiii. 207. † Ibid. p. 151.
‡ Ann. de Chim. et de Phys. liv. 208; or Annalen der Pharmacie, vi. 76.

When the roots of the *valeriana officinalis* are distilled with water, there pass over into the receiver, water and an oil; both of which contain valerianic acid. Saturate the water with carbonate of potash, and treat the oil with caustic potash ley. Concentrate the aqueous portion, add a sufficient quantity of sulphuric acid to saturate the potash, and distil to dryness. We obtain in the receiver an aqueous solution of valerianic acid, with a quantity of the same acid swimming upon it in the state of an oily hydrate.

Trommsdorf gives us also another process, namely, to distil the acid oil with carbonate of magnesia. The oil passes over into the receiver, while valerianate of magnesia remains in the retort. This salt is decomposed by adding the requisite quantity of sulphuric acid to combine with the magnesia.

Valerianic acid obtained by either of these processes, is in the state of a hydrate. We cannot deprive it of its water by distilling it off chloride of calcium, because this salt alters the nature of the acid, and seems to communicate muriatic acid.

But it may be partially deprived of its water by simple distillation, taking care to keep the receiver cool, and stopping the process when the drops which pass over cease to be milky.

Valerianic acid thus obtained, is a colourless, limpid, oleaginous liquid. It has a peculiar odour, having, however, considerable analogy with that of the root of valerian and the essential oil from the same plant. But it is more disagreeable, and cannot be removed either by animal charcoal, or any other process; but is diminished when the valerianic acid is combined with a base. The taste of the acid is very strong, very sour, and very disagreeable, and the impression of it remains long in the mouth. When very dilute, it leaves on the palate an impression of sweetness.

Its specific gravity at 50° is 0·944, that of water being unity. It remains liquid though cooled down to —6°. When heated in a platinum spoon, it readily catches fire, and burns with a strong flame, leaving no residue. It stains paper like an oil, but the stain may be completely removed by heat, without injuring the paper. It boils at the temperature of 270° under the pressure of the atmosphere; but it begins to evaporate at a much lower heat. This acid reddens litmus paper as powerfully as any of the mineral acids; but if the paper be left exposed to the atmosphere, its blue colour is very soon restored. When as well freed from water as possible, this acid requires 30 times its weight of water to dissolve it completely. Alcohol dissolves it in every proportion. A solution of equal parts of alcohol and valerianic acid becomes muddy when water is added; but it becomes again transparent if we add water in great excess and then agitate.

It is insoluble in oil of turpentine. If we agitate such a mixture it becomes milky, and the two liquids gradually separate from each other. The same thing happens when we agitate valerianic acid with olive oil.

It dissolves rapidly and abundantly in concentrated acetic acid, of

the specific gravity 1·07. Fuming sulphuric acid makes it yellow when added cold. If heat be applied, the valerianic acid is charred, and sulphurous acid disengaged. Nitric acid scarcely acts upon it, even when the two liquids are distilled together.

Valerianic acid dissolves iodine, but when water is added, a portion of the iodine is thrown down. Camphor dissolves in it also, slowly indeed, but abundantly. The solution is thick and colourless, and may be distilled over without alteration. When it is agitated with thirty times its weight of water the camphor is separated.

To determine the atomic weight of this acid, valerianate of barytes was formed by digesting the acid over carbonate of barytes in powder. The solution was crystallized *in vacuo* over sulphuric acid. The crystals were afterwards raised to the temperature of 266° and exposed to a current of dry air, till their water of crystallization was dissipated. This anhydrous salt was analyzed by ignition, in a platinum crucible, which converted it into carbonate of barytes. The mean of two analyses made in this way, gave

Valerianic acid . .	1·55 or 11·5
Barytes . . .	1·28 or 9·5

according to this analysis, the atomic weight is 11·5. This atomic weight was confirmed by an analysis of valerianate of silver, which was found composed of

Valerianic acid . . .	11·514
Oxide of silver . . .	14·5

M. Ettling, assistant to M. Liebig, analyzed the valerianic acid in these two salts, by heating determinate proportions of valerianate of barytes and of silver with oxide of copper. The results obtained gave the constituents as follows:—

	Salt of Barytes.	Salt of Silver.	Mean.
Carbon	64·97	63·65	64·310
Hydrogen	9·63	9·68	9·655
Oxygen	25·40	26·67	26·035
	100·00	100.00	100·000

From these we deduce the atomic constituents as follows:—

10 atoms carbon	=7·5	or per cent.	64·52
9 atoms hydrogen	=1·125	— —	9·67
3 atoms oxygen	=3·0	— —	25·81
	11·625		100·00

From this it appears, that the atomic weight of valerianic acid is 11·625, and that it differs from sebacic acid, by containing one atom more of hydrogen.

Valerianic acid in an isolated state, after having been rendered as anhydrous as possible, still retains an atom of water, being composed, according to M. Ettling's analysis, of

10 atoms carbon . .	=7·5
10 atoms hydrogen . .	=1·25
4 atoms oxygen . .	=4
	12·75

These numbers obviously differ from the preceding, by an atom of water, which raises the atomic weight from 11·625 to 12·75.

The valerianates, so far as they have been examined, possess the following properties.

They have a peculiar smell, and a sweet taste, leaving a sharp impression in the mouth. Some of them remain unaltered in the air, while others effloresce and some even deliquesce. Some may be obtained in regular crystals, while others only give amorphous crusts. Most of them have a slightly soapy feel. Some are soluble in water, while others are only imperfectly so. The greater number are soluble in alcohol.

They are all decomposed by heat. At the beginning of the action, valerianic acid is often disengaged unaltered. If to a concentrated solution of a valerianate, we add sulphuric, nitric, arsenic, phosphoric, muriatic, tartaric, malic, succinic, or acetic acid, valerianic acid immediately separates in an oleaginous state. Benzoic acid has no action on the valerianates. But valerianic acid decomposes the benzoates and carbonates.*

The following are the valerianates that have been particularly examined by Trommsdorf:†

1. *Valerianate of soda.* When a mixture of valerianic acid, water, and carbonate of soda is heated, carbonic acid gas is disengaged, and the valerianate of soda formed. The neutral solution is colourless, and does not crystallize when concentrated. By cautious evaporation we obtain a white mass, tallowy in appearance, and having a sweet taste. It is very soluble in absolute alcohol, absorbs moisture, and deliquesces in the air, and is very soluble in water. When heated to 266°, it becomes very soft: at 284°, it melts into a colourless transparent liquid without allowing any of the acid to escape. On cooling, it concretes into a snow-white mass. Its constituents, as determined by Trommsdorf, are

Valerianic acid . .	11·27
Soda	4
	15·27

2. *Valerianate of potash.* It may be obtained as the former salt. It is neutral, does not crystallize, has a very sweet taste, deliquesces in a moist atmosphere, and is very soluble in water and alcohol. It melts at 284°, without decomposition; but when raised to a higher temperature, decomposition takes places. Its analysis gave

Valerianic acid . .	11·62
Potash . . .	6
	17·62

3. *Valerianate of ammonia.* This salt may be formed, by adding an excess of carbonate of ammonia to the acid mixed with water. If it contain an excess of ammonia, it crystallizes in needles, having

* Trommsdorf, Ann. de Chim. et de Phys. liv. 218.
† Ann. de Pharmacie, vi. 190.

a sweet taste, leaving an impression of valerian. When these crystals are exposed to the air, they lose a portion of their base, and become acid. Trommsdorf could not obtain this salt in a state fit for analysis.

4. *Valerianate of lime.* This salt may be obtained by the same process as the preceding. The neutral solution is colourless, and yields, when concentrated, small prismatic crystals, united in the form of stars. When dried, the salt forms a brittle white mass. Its taste is very sweet. The crystals effloresce in a warm atmosphere, but remain unaltered in moist air. They dissolve readily in water and spirits, but scarcely in absolute alcohol. When heated to 284° it becomes soft, and loses some of its acid. In a higher temperature it melts, but becomes quite black, giving out a thick vapour, which burns with a light-coloured flame.

Its constituents, as determined by Trommsdorf, are

Valerianic acid . . .	11·53
Lime	3·5
	14·03

5. *Valerianate of barytes.* Prepared as the former salts. Its taste is sweet, with an impression of valerian oil. It crystallizes in prisms, dissolves readily in water, and is not altered by exposure to the air. By the analysis of Ettling, it is composed of

Valerianic acid . . .	11·5
Barytes	9·5
	21

6. *Valerianate of strontian.* It crystallizes in long four-sided tables, which effloresce in the air. It is pretty soluble in water, and dissolves also in alcohol, and the solution burns with a carmine-red flame. The taste is sweet, and somewhat sharp. It is composed, according to Trommsdorf, of

Valerianic acid . . .	11·6
Strontian	6·5
	18·1

7. *Valerianate of glucina.* Formed by dissolving carbonate of glucina in a mixture of water, and valerianic acid. The solution does not crystallize. When dried, it forms an opaque gummy-looking matter. The taste is very sweet, leaving an impression of astringency. It is not altered by exposure to the air. It is composed of

Valerianic acid . . .	11·73
Glucina	3·25

8. *Valerianate of zirconia.* Zirconia may be dissolved in valerianic acid by gentle boiling, but only in small quantity, and the solution has an acid reaction, yet it has a sweetish taste. By careful evaporation, the greatest part of the excess of valerianic acid is disengaged. No crystals are obtained, but a white dry mass, which

is not completely soluble in water. Zirconia seems to have a very weak affinity for valerianic acid.

9. *Valerianate of alumina.* When alumina, which has not been exposed to a red heat, is placed in contact with valerianic acid, combination speedily takes place. When hot water is added to the compound, no solution follows; but flocks swim in the liquid, which soon fall to the bottom. On cooling they concrete, and resemble tallow which has been melted and allowed to cool. Water dissolves merely a trace of this substance; nor is it soluble in valerianic acid. It is very soft, has a sweetish taste, and is insoluble in alcohol. According to Trommsdorf, it is composed of

Valerianic acid . . .	12·49
Alumina	2·25

It is obvious that it contained an excess of acid.

10. *Valerianate of magnesia.* A neutral salt which shoots into fine transparent prisms, they effloresce in dry air but remain unaltered in moist air. When the solution is evaporated no crystals are obtained but merely an amorphous mass. The taste is very sweet. Slightly soluble in alcohol. The salt is easily decomposed by heat. Trommsdorf found it composed of

Valerianic acid . . .	11·21
Magnesia	2·5

11. *Valerianate of Lead.* Metallic lead dissolves very slowly in valerianic acid, and carbonate of lead dissolves only in a boiling heat. The salt is soluble in boiling water. When digested with more oxide of lead, a subsalt is formed, which falls to the bottom. The neutral salt has a very sweet and astringent taste. When slowly evaporated it deposits white plates. When rapidly concentrated it forms a tough mass, which absorbs some moisture from the atmosphere, and is very soluble in water. It is composed, according to Trommsdorf's analysis, of

Valerianic acid . . .	11·63
Oxide of lead . . .	14

12. *Valerianate of silver.* Ettling formed this salt by mixing together solutions of nitrate of silver and valerianate of barytes, taking care to have a small excess of the latter salt. It falls down in white cheesy flocks, which after some days assume a crystalline texture. Its colour, when dried, is greyish white. It was dried at 266°, and was found a compound of

Valerianic acid . . .	11·5
Oxide of silver . . .	14·5
	26·0*

13. *Valerianate of cobalt.* Carbonate of cobalt dissolves in valerianic acid when assisted by heat. The solution has a rose-red colour, and does not crystallize. When dried, the salt is a violet red, transparent, foliated mass. When dissolved in as small a quantity of water as possible, so as to form a syrup, and left in a cold place,

* Ann. der Pharmacie, vi. 186.

it shoots into violet-red prismatic crystals. It is very soluble in water and alcohol, has a sweet and astringent taste, and is not altered by exposure to the air.

14. *Valerianate of copper.* Valerianic acid gradually dissolves copper, assuming a dark-green colour. When water is added to the saturated solution, the salt swims on the surface like a green oil. When the liquid is evaporated, it yields green prismatic crystals of neutral valerianate of copper. The salt dissolves readily in boiling water and alcohol. It is not altered by exposure to the air.

15. *Valerianate of nickel.* Valerianic acid does not act on metallic nickel; but it rapidly dissolves the carbonate when assisted by heat, assuming the appearance of a thick green oil. Boiling water dissolves a little of it; but the addition of alcohol occasions a complete solution of a light-green colour. By evaporation we obtain a light-green mass very difficultly soluble in water.

16. *Valerianate of iron.* Valerianic acid dissolves iron slowly, and gradually assumes a dark brownish-red colour. When water is added the salt separates under the form of a brown oil. The water is scarcely coloured, but caustic potash throws down a red precipitate showing that the iron is peroxidized. Newly precipitated hydrated peroxide of iron is slightly soluble in valerianic acid. We may form a neutral valerianate of iron by mixing together solutions of perchloride of iron and valerianate of soda. The light brown precipitate becomes darker when dried, and is very little soluble in water. It is doubtless a compound of

Valerianic acid . . .	11·5
Peroxide of iron . . .	5
	16·5

17. *Valerianate of mercury.* Mercury is not attacked by valerianic acid. But when red oxide of mercury is added by little and little to the hot acid, a combination takes place, having the appearance of a red transparent oil, which on cooling concretes into a mass of the consistency of ointment. If more oxide be added than the acid is capable of dissolving, the compound has a brownish-red colour. Cold water dissolves little of this salt, but boiling water dissolves the most of it, and from the hot filtered solution crystals of valerianate of mercury shoot, in soft white needles grouped in stars.

When the liquid from which the crystals were obtained is evaporated to dryness, a red insoluble matter remains, which is readily dissolved by valerianic acid when assisted by heat. When solutions of corrosive sublimate and valerianate of soda are mixed, neutral valerianate of mercury separates in soft white crystals, doubtless composed of

Valerianic acid . . .	11·5
Oxide of mercury . . .	13·5
	25

18. *Valerianate of zinc.* Carbonate of zinc dissolves readily in

valerianic acid when assisted by heat. When the solution is evaporated small shining plates are deposited resembling crystals of boracic acid. The taste is scarcely sweet but rather harsh. The salt dissolves easily in water and alcohol, and is not altered by exposure to the air. At 284° it melts into a syrup without losing any acid. It is doubtless composed of

Valerianic acid . . .	11·5
Oxide of zinc . . .	5·125
	16·625

19. *Valerianate of manganese.* The carbonate of manganese dissolves readily in valerianic acid when assisted by heat. The solution yields crystals in rhombic tables, they have a fatty feel, a strong lustre, and are readily soluble in water. This salt is doubtless composed of

Valerianic acid . . .	11·5
Oxide of manganese . . .	4·5
	16·

SECTION XIII.—OF BENZOIC ACID.

Benzoic acid, as it occurs in commerce, is usually contaminated with some resinous and oily matter. M. Righini has pointed out an economical method of purifying it. Dissolve the benzoic acid, to be purified in four or five times its weight of sulphuric acid previously diluted with six times its weight of water. When the solution is boiling, add a very small quantity of pure animal charcoal, filter, and allow the liquid to cool. The benzoic acid is deposited in crystals. If these crystals are not in long beautiful needles, and if they still retain any smell, the process is to be repeated. Collect the crystals on a filter, wash them with cold water to remove the sulphuric acid, and then allow them to dry in the shade. The sulphuric acid dissolves the resin and the oil with which the benzoic acid was contaminated, and thus leaves it in a state of purity.*

Benzoic acid, when pure, has no smell. It melts when heated to 248°, and boils at 473°. But it sublimes readily in a current of air when gently heated. It gives out vapours, even at the ordinary temperature of the atmosphere. When sublimed, it assumes the form of long flat prismatic needles, having a beautiful satin lustre. The specific gravity of its vapour is about 4·27.†

The crystals of benzoic acid were analyzed by MM. Wöhler and Liebig, and found composed of

Carbon	68·04 or	14 atoms =	10·5	or per cent.	68·85
Hydrogen	5·02 or	6 atoms =	0·75	— —	4·91
Oxygen	26·94 or	4 atoms =	4	— —	26·24
	100‡		15·25		100·00

* Ann. de Chim. et de Phys. lvi. 443. † Mitscherlich and Dumas.
‡ Ann. de Chim. et de Phys. li. 282.

But when anhydrous benzoate of silver was analyzed, it was found composed of

Benzoic acid	.	49·46 or 14·19
Oxide of silver	.	50·54 or 14·5
		100·00

The acid in benzoate of silver being subjected to an ultimate analysis with oxide of copper, yielded

Carbon	73·30 or	14 atoms =	10·5	or per cent.	74·34
Hydrogen	4·56 or	5 atoms =	0·625	— —	4·42
Oxygen	22·14 or	3 atoms =	3·0	— —	21·24
			14·125		100

Thus it appears, that the atomic weight of benzoic acid is 14·125, and that the crystals consist of 1 atom of the acid united with 1 atom water.

SECT. XIV.—OF CINNAMONIC ACID.

This name has been given by Dumas and Peligot to a substance which occasionally appears in old oil of cinnamon, in large reddish-yellow crystals, and which has been noticed by various chemists, and confounded with benzoic or succinic acid, or with camphor.

Cinnamon is the inner bark of the branches of the *Laurus cinnamomum*, a tree which grows in Ceylon, and in various other parts of the East Indies. Though known to the ancients, and used by them in their religious services, they seem to have been ignorant of the country whence it was imported, as both Herodotus and Pliny mention Africa as its place of nativity. The celebrated Benjamin Robins sent a specimen of the cinnamon tree to Sir William Watson, who gave an account of it in the *Philosophical Transactions* for 1751.* Of late years, much of the cinnamon of commerce comes from China, and is known by the name of *Cassia*. It is the produce of another species of tree, the *laurus cassia*.

When cinnamon is distilled in the usual way, it yields a small quantity of a volatile oil, to which the bark is indebted for its taste and smell. Two varieties of oil of cinnamon occur in commerce, one obtained from the cinnamon of Ceylon, the bark of the *laurus cinnamomum*; the other from *cassia*, the bark of the *laurus cassia*. The latter of these has a reddish-brown colour, a disagreeable smell resembling that of bugs, and sells at about thirty shillings the pound weight. The oil of cinnamon from Ceylon, has an agreeable smell, and sells at a much higher price.

As this oil never occurs pure in commerce, MM. Dumas and Peligot, who undertook to examine its properties, prepared a quantity of it from Chinese cassia. They reduced the bark to powder, steeped it for twelve hours in water saturated with salt, and then distilled it over the naked fire. A milky water came over, which

* Vol. xlvii. 301.

gradually deposited its oil. This oil being distilled off chloride of calcium was considered as pure.

Oil of cinnamon resembles camphor strongly, in the way that concentrated nitric acid acts upon it. It concretes almost immediately, and forms with it a true crystalline salt, in which the oil of cinnamon acts the part of a base. This combination takes place imperfectly when the common oil of commerce is used, but the pure oil, when mixed with nitric acid, crystallizes directly.

Oil of cinnamon combines with muriatic acid gas; but it assumes a greenish colour, indicating some alteration in its nature, which does not take place when it is combined with nitric acid.

It combines with ammonia, and forms a crystallized product which is not altered by exposure to the atmosphere. Thus it has the curious property of combining both with acids and bases, and forming definite compounds with both.

Oxygen gas is rapidly absorbed by oil of cinnamon, especially when moist, and an acid is formed to which Dumas and Peligot have given the name of *cinnamonic acid*. We shall give an account of the properties of this acid after we have made a few observations on oil of cinnamon, which obviously constitutes its base.

When oil of cinnamon is subjected to the action of hot nitric acid the smell of bitter almonds becomes perceptible, and when the acid ceases to act on the oil we find a great quantity of benzoic acid in the residue.

When this oil is boiled with hypochlorite of lime a great quantity of benzoic acid is formed, or rather of benzoate of lime.

When we heat it with an aqueous solution of potash, it does not appear to undergo any alteration. But if we heat it with hydrate of potash, a great quantity of pure hydrogen gas is driven off and cinnamate of potash is formed.

When a current of chlorine is passed through the oil, a liquid chloride is at first formed, which appears to correspond with chloride of benzoyl; but if we heat the oil and cause it to absorb as much chlorine as it will take up, we obtain a crystallized substance approaching chloral in its constitution.*

From the preceding account of the properties of oil of cinnamon, as determined by Dumas and Peligot, it is obvious that it is very analagous to oil of bitter almonds. They consider it as a compound of hydrogen and the base of cinnamonic acid, to which they have given the name of *cinnamoyl*. The oil they distinguish by the name of *hydret of cinnamoyl*. But while the hydret of benzoyl forms only combinations in which the radical of benzoic acid always appears unaltered, the hydret of cinnamoyl often undergoes a molecular alteration, which destroys its proper radical, which is replaced by the radical of benzoic acid. This shows that the radical of cinnamonic acid is much less stable than the radical of benzoic acid; a circumstance which renders its investigation considerably more difficult.

* Ann. de Chim. et de Phys. lvii. 308.

Dumas and Peligot subjected oil of cinnamon to an ultimate analysis by means of oxide of copper, and obtained

Carbon	80·6	or 18 atoms	= 13·5	or per cent.	81·80
Hydrogen	6·4	or 9 atoms	= 1·25	— —	6·77
Oxygen	13·0	or 2 atoms	= 2·0	— —	12·03
	100		16·625		100·00

M. Blanchet has also analyzed oil of cinnamon.* He obtained

Carbon	80·3	or 18 atoms	= 13·5	or per cent.	80·60
Hydrogen	7·7	or 10 atoms	= 1·25	— —	7·47
Oxygen	12·0	or 2 atoms	= 2·0	— —	11·93
	100		16·78		100·00

If it be a hydret of cinnamoyl it is obvious that cinnamoyl must be C^{18} H^{8} O^{2} or C^{18} H^{9} O^{2}.

Cinnamonic acid frequently occurs in old oil of cinnamon in large yellow crystals. These crystals are prisms, they dissolve in boiling water, which, on cooling, deposits the pure acid in colourless pearly plates. As the acid is but little soluble even in hot water, it is necessary to digest the impure crystals in successive portions of boiling water as long as the liquid continues, on cooling, to deposit the pearly plates. This acid was subjected to an ultimate analysis, by Dumas and Peligot; by means of oxide of copper, they obtained

Carbon	72·44	or 18 atoms	= 13·5	or per cent.	72·97
Hydrogen	5·66	or 8 atoms	= 1	— —	5·41
Oxygen	21·90	or 4 atoms	= 4	— —	21·62
	100		18·5		100·00

Two different analyses of cinnamate of silver were made, the mean of which gave its constituents

Cinnamonic acid	.	54·9 or 17·65
Oxide of silver	.	45·1 or 14·5
		100·0

It is obvious that the cinnamonic acid analyzed, contained an atom of water, while the acid in the cinnamate of silver was anhydrous. To verify this, Dumas and Peligot analyzed the cinnamonic acid in the cinnamate of silver, and obtained

Carbon	76·41	or 18 atoms	= 13·5	or per cent.	77·71
Hydrogen	5·32	or 7 atoms	= 0·875	— —	5·03
Oxygen	18·27	or 3 atoms	= 3·0	— —	17·26
			17·375		100·00

It is obvious from these analyses, that cinnamonic acid has an atomic weight of 17·375, and that its constitution is expressed by the formula, C^{18} H^{7} O^{3}. The crystals after being dried *in vacuo*, still retain an atom of water.

* Poggendorf's Annalen, xxxiii. 58.

Let us now compare the constitution of oil of cinnamon and cinnamonic acid.

Oil of cinnamon is . . .	$C^{18}\ H^{8}\ O^{2}$
Cinnamonic acid . . .	$C^{18}\ H^{7}\ O^{3}$

We see that the oil is converted into cinnamonic acid, by depriving it of an atom of hydrogen, and adding an atom of oxygen.

The base of cinnamonic acid or cinnamoyl is $C^{18}\ H^{7}\ O^{2}$. Oil of cinnamon is a hydret of that base, or $C^{18}\ H^{7}\ O^{2} + H$, and cinnamonic acid $C^{18}\ H^{7}\ O^{2} + O$.

Cinnamonic acid is colourless. It melts at 248° and boils at 559°. At that temperature it may be completely distilled over without leaving any residue. When slowly heated, it sublimes in brilliant plates, very similar to the crystals of benzoic acid. Its vapour has a strong odour, and excites coughing.

It is very little soluble in cold water, but hot water is a better solvent; and this solution, on cooling, concretes into a gelatinous crystalline mass, having a pearly lustre.

Alcohol is a good solvent of this acid, and it is precipitated from its solution by water. It combines with bases, and forms salts, which, in general, have a striking resemblance to the corresponding benzoates; but hitherto the properties of these salts have not been much examined.

Nitric acid decomposes cinnamonic acid; red vapours are disengaged, and oil of bitter almonds formed, and finally benzoic acid is deposited.*

Dumas and Peligot have also examined the action of chlorine, nitric acid, muriatic acid, and ammonia, upon oil of cinnamon; and have shown that the compounds formed may be thus represented:

Chloride of cinnamoyl .		$C^{18}\ H^{7}\ O^{2} + Chl$
Nitrate of cinnamoyl	1 atom cinnamoyl	$C^{18}\ H^{7}\ O^{2}$.
	1 atom nitric acid	$O^{5}\ Az$
	1 atom water	$H\ O$
		$C^{18}\ H^{7}\ O^{2} + Az\ O^{5} + H\ O$
Muriate of oil of cinnamon		$C^{18}\ H^{8}\ O^{2} + H\ Chl$
Ammoniated oil of cinnamon		$C^{18}\ H^{8}\ O^{2} + H^{3}\ Az$

SECTION XV.—OF HIPPURIC ACID.

Rouelle was the first person who discovered the existence of benzoic acid in the urine of the horse.† Fourcroy and Vauquelin announced, that this benzoic acid existed in the urine of the horse in the state of benzoate of soda.‡ Scheele, and after him Fourcroy and Vauquelin, found that the same acid existed in the urine of infants. This discovery was confirmed by the subsequent experiments of Proust and Thenard. In 1834, M. Liebig§ resumed the examination of the urine of the horse, and satisfied himself by nu-

* Dumas and Peligot, Ann. de Chim. et de Phys. lvii. 311.
† Jour. de Medicine, 1777. ‡ Mem. de l'Institute, ii. 431.
§ Annalen der Pharmacie, xii. 20.

merous experiments, that the acid contained in it was not the benzoic, as hitherto supposed; but another easily convertible into benzoic acid, and which he distinguished by the name of *hippuric acid.**

To obtain it, he concentrated the urine of the horse, and mixed it with muriatic acid in slight excess. On setting the mixture aside, yellowish-brown crystals were deposited, having a peculiar and disagreeable smell. When these crystals were dissolved in water, and the solution boiled with animal charcoal, the liquid, after filtration, was colourless: and the concentrated solution, on cooling, deposited large semitransparent brittle crystals, which constituted pure *hippuric acid.*

When hippuric acid is heated it melts, undergoes decomposition, and becomes black; while, at the same time, benzoic acid sublimes, and a very distinct odour of bitter almonds is observed, and a great quantity of porous charcoal remains. When mixed and heated with four times its weight of hydrate of lime, it allows a great deal of ammonia to be disengaged, while, at the same time, a volatile oil passes over into the receiver.

Sulphuric acid dissolves hippuric acid with facility, without blackening, at the temperature of 248°, and water throws it down again unaltered. But when the sulphuric acid solution is heated above 248°, sulphurous acid and benzoic acid are disengaged. It dissolves with equal facility in nitric acid; but by a boiling heat, it is entirely converted into benzoic acid, though scarcely any nitrous or carbonic acid is evolved. It dissolves in hot muriatic acid, and when the solution cools the hippuric acid crystallizes, possessed of all its properties: an excess of chlorine does not attack it; but when boiled with a great excess of hypochlorite of lime, it is converted into benzoic acid.

Liebig subjected anhydrous hippuric acid to an analysis by means of oxide of copper.

He found hippurate of silver composed of

Hippuric acid . .	61·09 or 22·79
Oxide of silver . .	38·91 or 14·5
	100·00

This would make the atomic weight of hippuric acid 22·79. But Dumas and Peligot, who repeated the analysis with great care, obtained

Hippuric acid . .	59·9 or 21·65
Oxide of silver . .	40·1 or 14·5
	100·0†

This makes the atomic weight only 21·65.

The same chemists subjected hippuric acid to an analysis with oxide of copper.

* Form ἵππος, *a horse,* and οὖρον, *urine.*

† Ann. de Chim. et de Phys. lvii. 329.

The following table shows the constituents of this acid according to the two analyses.

	Liebig.	Dumas and Peligot.
Carbon	60·7392	60·68
Hydrogen	4·9588	5·21
Azote	7·8518	7·70
Oxygen	26·4502	26·41
	100·0000*	100†

These numbers very nearly agree. They indicate for the atomic constitution of hippuric acid,

18 atoms carbon	=	13·5	or per cent.	60·34
9 atoms hydrogen	=	1·125	— —	5·02
1 atom azote	=	1·75	— —	7·82
6 atoms oxygen	=	6·00	— —	26·82
		22·375		

Now, 22·375 is nearly the mean of the atomic weights deduced by Liebig and Dumas and Peligot from their respective analyses.

Dumas and Peligot are of opinion, that hippuric acid, as analyzed both by themselves and by Liebig, contained an atom of water. If that supposition be well founded, its constitution, supposing it anhydrous, will be

18 atoms carbon	. .	= 13·5
8 atoms hydrogen	. .	= 1
1 atom azote	. .	= 1·75
5 atoms oxygen	. .	= 5
		21·25

and its atomic weight 21·25.

We can now see how hippuric acid is converted into benzoic acid,

Hippuric acid is	.	$C^{18}\ H^{8}\ Az\ O^{5}$
Benzoic acid is	.	$C^{14}\ H^{5}\ \ O^{3}$
Remain	. . .	$C^{4}\ H^{3}\ Az\ O^{2}$

$H^3\ Az$ is an atom of ammonia. There remains $C^4\ O^2$. If we add 2 atoms of water and 2 atoms of oxygen, we get 2 atoms of formic acid $C^4\ H^2\ O^6$. Thus it appears that hippuric acid is capable, with the addition of water and oxygen, of being converted into 1 atom benzoic acid, 1 atom ammonia, and 2 atoms formic acid. Now when Dumas and Peligot treated hippuric acid with hypochlorite of lime, saturated the liquids and heated them with nitrate of silver, or a salt of mercury, metallic silver or mercury was always precipitated, a phenomenon which characterizes formic acid.

Hippuric acid readily dissolves the greater number of the bases. Its soluble salts precipitate the peroxide of iron with the colour of

* Poggendorf's Annalen, xxxii. 573.
† Ann. de Chim et de Phys. lvii. 326.

rust. They precipitate the nitrates of silver, and suboxide of silver, in white heavy flocks.

1. *Hippurate of ammonia.* The neutral salt crystallizes with difficulty, but the supersalt readily. When the neutral salt is evaporated it gives out ammonia. When evaporated to dryness, it melts and assumes a red colour. This residue is soluble in hot water, and the liquid on cooling deposits red crystals, which have the characters of hippuric acid.

2. *Hippurates of potash, soda, and magnesia.* These salts are very soluble and difficultly crystallizable.

3. *Hippurate of barytes.* When we boil hippuric acid over carbonate of barytes, we obtain a liquid which reacts as an alkali, and which, when evaporated, assumes the form of a jelly. When allowed to cool, it constitutes conical masses, having a white colour like porcelain. This white matter, after having been dried *in vacuo*, melts, when greatly heated, without diminishing in weight, and forms a clear liquid, which, on cooling, is converted into a transparent glass.

If we dissolve this subsalt in water, and add dilute acetic acid till it becomes sensibly acid, we obtain by evaporation white transparent plates of neutral hippurate of barytes.

4. *Hippurate of lime.* This salt is prepared by heating the acid with carbonate of lime. It crystallizes on cooling in rhombic prisms, and by evaporation we obtain it in large shining plates. It dissolves in 18 times its weight of cold, and 6 times its weight of boiling water. Its taste is bitter and sharp.

5. *Hippurates of cobalt and nickel.* The salts of cobalt and nickel are not precipitated by hippuric acid. The carbonate of cobalt dissolves readily in that acid, and the concentrated solution deposits red needles, which contain water of crystallization.

6. *Hippurate of lead.* Oxide of lead when heated with water and hippuric acid is partly dissolved. Another portion of it forms a tough mass which remains at the bottom of the vessel, and is easily decomposed and blackened even under water. The portion dissolved constitutes a subsalt, which, by evaporation, forms a tough shining skin on the surface of the liquid. When sufficiently concentrated it constitutes a white mass.

The neutral salt may be obtained by mixing together solutions of a salt of lead and a hippurate. On cooling, the salt is deposited in silky needles, which when dried become tender, and assume a pearly lustre. In a dry atmosphere they become opaque and white. This salt is soluble in between 5 and 6 times its weight in water.

7. *Hippurate of copper.* The carbonate or hydrous oxide of copper dissolves readily in hippuric acid. The salt crystallizes in blue needles so united as to constitute stars. At a high temperature these needles lose their water of crystallization and become green.

8. *Hippurate of silver.* Obtained by mixing concentric solutions of hippurate of potash and nitrate of silver. It is deposited in white flocks. When the solutions are dilute, the salt is slowly deposited in crystalline grains. Its constituents are

1 atom hippuric acid . .	21·25
1 atom oxide of silver . .	14·5
	35·75*

From the experiments of Dr. C. G. Lehman of Leipsig, it would appear that hippuric acid is gradually formed in diabetic urine after it has been voided.†

SECTION XVII.—OF ESCULIC ACID.

This acid was discovered by M. Fremy; but the only account of it hitherto published, is in the 5th volume (p. 296) of Dumas' *Traité de Chimie appliquée aux Arts.*

M. Fremy, by treating horse chestnuts (the fruit of *Esculus hippocastanum*) with alcohol of 0·834, and evaporating the liquid, obtained a light yellow viscid matter, which was deposited in flocks. It had a very striking resemblance to the substance extracted by M. Bussy, from the Saponaria of Egypt‡ which he called *saponin.*

When saponin, or the substance from the horse chestnut is digested in acids cold, no change is produced. But when the temperature is raised to 195° or to 212° a white matter instantly precipitates, which is *esculic acid.*

Esculic acid is insoluble in water, soluble in alcohol, and is deposited from that solution in crystalline grains. It dissolves in hot nitric acid, nitrous acid being disengaged, and is converted into a yellow resin. This resin dissolves in potash, but when precipitated from the solution by an acid it still retains azote as a constituent.

We do not know the atomic weight of this acid; but it has been subjected to an ultimate analysis by means of oxide of copper. The constituents are

Carbon	58·19 or 52 atoms	=	39·	or per cent	56·7
Hydrogen	8·27 or 46 atoms	=	5·75	— —	8·3
Oxygen	33·54 or 24 atoms	=	24·	— —	35
			68·75		100·0

These numbers given by M. Dumas, do not accord very well with the analysis; but it is not worth while to correct them till the atomic weight of esculic acid be determined.

The esculates of potash, soda, and ammonia, are too soluble in water to crystallize. When concentrated sufficiently, they assume the form of a jelly. They are insoluble in alcohol of 0·817, and crystallize in pearly plates in alcohol of 0·928. All the other esculates are insoluble in water; but they all dissolve, and some of them crystallize in weak alcohol.

Esculic acid and saponin, have some resemblance to a substance found in sarsaparilla, which has been distinguished by the name of *sarsaparillin.*

* Dumas' Chimie appliquée aux Arts, v. 220.
† Jour. de Pharm. xxii. 142. ‡ *Gypsophila struthium.*

It may be worth while to make a few observations on the *saponin*, extracted by Bussy, from the *gypsophila struthium*,* because it is very intimately related to, if not quite the same as, the saponin from the horse chestnut.

To obtain it, M. Bussy digests the saponaria of Egypt in boiling alcohol of 0·834. After some minutes' boiling, the alcohol is filtered and left to cool. The saponin partly precipitates. It is collected on a cloth. And this treatment is repeated till the root is exhausted.

Saponin thus obtained is white, incrystallizable and friable. It has an acrid and sharp taste, which remains long in the mouth. When in powder, it acts as a powerful sternutatory. It is soluble in water in all proportions. The solution is at first muddy, but it gradually acquires transparency, by being repeatedly filtered. It froths strongly when agitated, even when it contains only $\frac{1}{1000}$th of its weight of saponin.

The same weight of it does not form a mucilage so thick as gum does. When the solution is evaporated, it leaves a shining varnish, easily detached from the vessel and reduced to powder.

Alcohol of all strengths dissolves saponin; the weak spirits in all proportions, while absolute alcohol dissolves only one-fifth of its weight of it. Ether does not act upon it. It burns in the air and emits an aromatic smell. When distilled it blackens, swells, and gives off an acid empyreumatic oil.

Boiling acids, according to M. Fremy, convert it into esculic acid. Boiling nitric acid, according to M. Bussy, decomposes it, forming a yellow resin, mucic acid, and oxalic acid. Weak alkalies have no action on it while cold; but boiling potash changes it into esculate of potash.

Its constituents, according to the analysis of M. Bussy, are

Carbon	51·3 or 26 atoms =	19·50
Hydrogen	7·4 or 23 atoms =	2·875
Oxygen	41·3 or 16 atoms =	16·0
	100·0	79·375

M. Bussy found the compound of saponin and oxide of lead, composed of

Saponin . . .	72·8 or 37·47
Oxide of lead . .	27·2 or 14
	100·0

* Jour. de Pharmacie, xix. 1.

CHAPTER II.

OF FIXED ACIDS.

In the preceding Chapter an account has been given of those vegetable acids which may be volatilized by heat without decomposition. But by far the greatest number are decomposed when heat is applied; and, in general, when the requisite care is taken not to carry the heat too far, new acids are formed, possessing properties quite different from those by the decomposition of which they have been obtained. Only eight of these fixed acids have been hitherto subjected to these experiments. But there cannot be any doubt that most, if not all, of the remaining fixed acids, as soon as they are properly examined, will be found to yield similar products.

The following table exhibits a view of the composition of these eight acids, with the names and constitution of the acids obtained by their decomposition :—

Acids.	Composition.	Derivative Acids.	Composition.
1 Malic	$C^4\ H^2\ O^4$	1 Maleic or Equisetic	$C^4\ H\ O^3$
		2 Paramaleic or Fumaric	Do.
2 Citric	Do.	3 Pyrocitric	$C^5\ H^2\ O^3$
		4 Citricic	Do.
3 Tartaric	$C^4\ H^2\ O^5$	5 Pyrotartaric	$C^5\ H^3\ O^3$
		6 Pyruvic	$C^6\ H^3\ O^5$
4 Racemic	Do.	Yields similar acids.	
4 Oxalhydric	$C^4\ H^3\ O^6$		
5 Mucic	$C^6\ H^4\ O^7$	7 Paramucic	$C^6\ H^4\ O^7$
		8 Pyromucic	$C^{10}\ H^3\ O^5$
6 Meconic	$C^7\ H^2\ O^7$	9 Pyromeconic	$C^{10}\ H^3\ O^5$
		10 Metameconic	$C^{12}\ H^4\ O^{10}$
7 Gallic	$C^7\ H^3\ O^5$	11 Pyrogallic	$C^6\ H^3\ O^3$
		12 Metagallic	$C^{12}\ H^3\ O^3$
8 Kinic	$C^{15}\ H^9\ O^9$	13 Pyrokinic.	

The following table gives the composition of the remaining fixed vegetable acids, which have been hitherto investigated with tolerable accuracy :—

1	Ellagic	$C^7\ H^2\ O^4$
2	Cahincic	$C^{7\frac{1}{4}}\ H^6\ O^{3\frac{1}{2}}$
	Bicoloric	$C^8\ H^{4\frac{1}{4}}\ O^5$
3	Caffeic	$C^{12}\ H^{17}\ O^{19}$
	Picrotoxic	$C^{12}\ H^7\ O^5$
4	Japonic	$C^{12}\ H^4\ O^4$
5	Mechloic	$C^{14}\ H^7\ O^{10}$
6	Catechuic	$C^{15}\ H^5\ O^5$
7	Amygdalic	$C^{40}\ H^{26}\ O^{24}$
8	Tannic	$C^{18}\ H^8\ O^{12}$
9	Rubinic	$C^{18}\ H^6\ O^9$
10	Ulmic	$C^{30}\ H^{15}\ O^{15}$

We shall give an account of all these acids in the following Sections :—

SECT I.—OF MALIC ACID.

In the account of malic acid given in the *Chemistry of Inorganic Bodies* (ii. 76), two different analyses of it are stated, one by Prout and another by Frommrerz. These two were utterly irreconcilable with each other. In consequence of which it was impossible to come to any satisfactory conclusion respecting the constitution of this acid. The subject has been since taken up by Liebig,* who has shown that malic and citric acids are isomeric bodies. He obtained, as the result of a very careful analysis, for the constituents of malic acid,

41·02 or 4 atoms carbon	= 3	or per cent.		41·37
3·51 or 2 atoms hydrogen	= 0·25	—	—	3·45
55·47 or 4 atoms oxygen	= 4	—	—	55·18
	7·25			100·00

Liebig analyzed several of the malates, and showed that the atomic weight of malic acid is 7·25.

1. *Malate of silver.* When fused nitrate of silver and bimalate of ammonia are mixed together, we obtain a granular precipitate, having a brilliant white colour, but becoming yellow when dried. If we heat it after it has been dried, it swells up and undergoes decomposition, giving out an empyreumatic odour. Metallic silver remains in a state of purity, which adheres firmly to the porcelain crucible in which the experiment was made. Its constituents are

Malic acid . .	33·41 or 7·33
Oxide of silver . .	66·59 or 14·5
	100

If we admit that the malate of silver analyzed by Liebig contained 0·12 per cent. of water, then the quantity of malic acid, in 100 grains will be 33·29 grains, and the atomic weight will be exactly 7·25.

When citrate of silver is heated it behaves quite differently from malate of silver. It requires to be heated with the utmost caution. At a certain temperature it makes a kind of explosion, and the whole crucible is filled with light spongy flocks of metallic silver.

Both malate and citrate of silver dissolve readily in boiling water. When the solution of malate cools, small crystals are deposited, the liquid blackens, and lets fall metallic silver. The solution of citrate of silver, in the same circumstances, deposits groups of concentric needles having a yellowish-white colour.

2. *Malate of zinc.* The constituents of this salt are

Malic acid . . .	63·08 or 8·75
Oxide of zinc . .	36·92 or 5·125
	100

It is obvious that this salt contained either an excess of acid, or still retained water.

The crystallized malate of zinc contains 3 atoms of water, which it loses when heated to between 212° and 248°.

* Annalen der Pharmacie, v. 141.

3. *Malate of magnesia.* The crystals of this salt effloresce when exposed to the air. They are at first transparent, but become gradually opaque and white. When dried at a temperature between 212° and 302°, it loses from 29·5 to 30 per cent. of water. But about one-fourth of its water still remains, which cannot be driven off even by the heat of a boiling solution of concentrated chloride of calcium. The crystals are composed of

1 atom malic acid . . .	7·25
1 atom magnesia . . .	2·5
5 atoms water . . .	5·625
	15·375

Heat drives off 4 of the 5 atoms; but the other remains obstinately fixed at the greatest heat which can be applied without decomposing the acid.

4. *Malate of barytes.* It is very difficult to saturate malic acid by means of carbonate of barytes. When the solution is evaporated, white crusts are deposited which have no appearance of crystallization. They are insoluble in water, whether hot or cold, but dissolve rapidly when a little acid is added, and the liquid is not precipitated by ammonia. In this state it is anhydrous, and composed of

1 atom malic acid . . .	7·25
1 atom barytes . . .	9·5
	16·75

From Liebig's analysis the dry salt seems still to retain 0·488 per cent. of water.

After the neutral malate of barytes is deposited, if we continue to evaporate the solution, we obtain a supermalate of barytes, which is very soluble in water. Liebig did not succeed in his attempts to form a submalate of barytes.*

The crystals of malic acid are composed of

1 atom malic acid . . .	7·25
1 atom water . . .	1·125
	8·375

They lose no weight at 248°, and can only be deprived of their water by combining them with a base. Malic acid melts at 181°. At 349° it is decomposed and resolved into water and two pyroacids, which are isomeric.†

SECTION II.—OF EQUISETIC OR MALEIC ACID.

It was ascertained by Pelouze, that when malic acid is distilled at the temperature of 349°, it is resolved into water, and two pyroacids, which are isomeric. These acids have been distinguished by the names of *equisetic* or *maleic*, and *fumaric* or *paramaleic acid*.‡ Of these acids, the maleic is the most, and the paramaleic acid the least volatile. At 392°, much more maleic acid is formed than

* Ann. de Chim. et de Phys. lii. 434. † Ibid. lvi. 72. ‡ Ibid.

paramaleic. At 302°, scarcely any thing else is formed than water and paramaleic acid.

Maleic acid crystallizes in oblique four-sided prisms. It has no smell, but a very acid taste; and it leaves a very disagreeable impression in the mouth. It is very soluble in water and alcohol.

It melts at 266°, and boils at 320°. At that temperature the crystals are decomposed into water, and anhydrous maleic acid. When kept in a temperature a little above its melting point, it is gradually transformed into crystals of paramaleic acid, and the heat may be raised to 392° without volatilizing or melting these crystals.

When maleic acid is dissolved in water and left to spontaneous crystallizations, the crystals run up the sides of the vessel and make their way over it.

Maleic acid is not precipitated by lime water. With barytes water a precipitate falls, which speedily assumes the form of small crystalline grains. The precipitate is re-dissolved, when an excess either of maleic acid or of barytes is added.

No precipitate falls when this acid is dropt into solutions of chloride of barium, chloride of calcium, sulphated peroxide of iron, or nitrate of silver.

When concentrated solutions of maleate of potash, and chloride of calcium are mixed together, no precipitate falls; but after an interval of some days, we find a deposition of crystalline needles of maleate of lime.

Acetate of lead occasions a white precipitate when dropt into very dilute solutions of maleic acid. This precipitate speedily assumes the form of brilliant plates. When the solutions are concentrated, and the lead in excess, the whole assumes the appearance of a white tremulous mass like starch mucilage.

Maleates of potash, soda, and ammonia, are very soluble. The last is incrystallizable.

Maleate of barytes is obtained, by saturating a concentrated solution of maleic acid with barytes water. In a few minutes the liquid assumes the form of a white jelly. When dried, it is in small crystalline plates, and is composed of

1 atom maleic acid . .	6·125
1 atom barytes . . .	9·5
1 atom water . . .	1·125
	16·75*

Maleate of silver is anhydrous, and slighly soluble in water. When heated to 300° or 302°, it is decomposed all at once, and changed into a dark-grey matter, having the metallic lustre, and into carbonic acid. At the same time, on the sides of the vessel, there appear yellow crystallizable drops, having a very sour taste. The residue washed in water, acidulated with muriatic acid till nothing more is dissolved, effervesces with nitric acid, and leaves black flocks of charcoal. It was a bicarburet of silver.†

* Regnault, Jour. de Pharm. xxiii. 31. † Regnault, ibid.

Maleates of copper and iron are less soluble.

Those maleates which contain a vegetable alkaloid for a base, are in general, easily crystallizable and soluble.

Maleate of lead is a neutral salt containing three atoms of water.

To determine the atomic weight of maleic acid, M. Pelouze analyzed maleate of lead, and found its constituents, when dried, at 248°,

Maleic acid . .	30·95 or 6.27
Oxide of lead . .	69·05 or 14
	100·00

It would appear from this, that the atomic weight of the acid is 6·25.

He analyzed maleic acid, dried *in vacuo* over sulphuric acid, by means of oxide of copper, and obtained

Carbon	40·745
Hydrogen	3·511
Oxygen	55·744
	100·000

Liebig* found that 0·838 parts of paramaleate of silver gave 0·724 of chloride of silver. This gives 6·25 for the atomic weight of the acid. He analyzed the two acids, and found their composition as follows:—

	Maleic.	Paramaleic.
Carbon	40·83	40·74
Hydrogen	3·50	3·52
Oxygen	55·67	55·74
	100·00	100·00

Upon analyzing maleate of lead, dried at the temperature of 248° by means of oxide of copper, Pelouze obtained, for the ultimate constituents of maleic acid,

Carbon	48·41 or 4 atoms	= 3	or per cent 48·98
Hydrogen	2·29 or 1 atom	= 0·125	— — 2·04
Oxygen	49·30 or 3 atoms	= 3	— — 48·98
	100	6·125	100

So that the true atomic weight of maleic acid is 6·125, and the crystals contained an atom of water.†

Crystals of maleic acid are rendered anhydrous by repeated distillations. The acid then melts at 134½° and boils at 349°. In this state, it is more decomposible by heat than when it contains water; but its ultimate constituents are the same.

The composition of malic acid is $C^4\ H^2\ O^4$. Hence it is resolvable into $C^4\ HO^3 + HO$, or an atom of maleic acid, and an atom of water.

It is remarkable, that although citric and malic acids be isomeric,

* Ann. der Pharm. xi. 276. † Pelouze, Ann. de Chim. et de Phys. lvi. 72.

yet the constitution of pyrocitric and maleic acids is quite different. The probable reason of this is the difference which exists between the water of crystallization of the two acids, showing pretty clearly that the proportion of that water influences the decomposition by heat.

M. Braconnot discovered an acid in the *equisetum fluviatile*, which he distinguished by the name of *equisetic acid*.* This acid, which exists in the juice of the *equisetum fluviatile* and *limosum*, combined with magnesia, has been lately examined by M. Regnault, and shown to be identical with maleic acid.† Malic acid, then, is not only an artificial product from the decomposition of maleic acid by heat, but is formed also by the processes of vegetation in more than one species of equisetum.

SECT. III.—OF FUMARIC, LICHENIC, OR PARAMALEIC ACID.

It has been already stated that when malic acid is kept at the temperature of 302°, it undergoes decomposition, and scarcely anything else is formed except water and paramaleic acid.

The crystals of paramaleic acid are large striated prisms; sometimes rhomboidal, sometimes six-sided. It has a simply acid taste. It requires for solution 200 times its weight of water, while maleic acid dissolves in 100 times its weight of that liquid. It is very difficult of fusion, and requires a higher temperature than 392° in order to be volatilized.

Lime, barytes, and strontian water occasion no precipitate. It precipitates acetate of lead, but the precipitate does not crystallize. When heated, the precipitate re-dissolves, and, on cooling, is again deposited in irregular crystals.

Though paramaleic acid be diluted with 200,000 times its weight of water, it gives a sensible white precipitate with nitrate of silver.

Paramaleate of potash throws down silver so completely from its solutions that no trace of it can afterwards be found by means of muriatic acid.

The paramaleates of copper and iron are very little soluble in water.

Paramaleate of potash crystallizes in prismatic plates, radiating from a centre. Paramaleate of lead is composed of

1 atom paramaleic acid . .	6·125
1 atom oxide of lead . .	14
3 atoms water . . .	3·375
	23·5

M. Pelouze and M. Liebig analyzed the crystals of paramaleic acid by means of oxide of copper, and found them identic in composition with maleic acid.

Pelouze found paramaleate of lead dried at 284° composed of

Paramaleic acid . .	246 or 6·31
Oxide of lead . .	545 or 14
	20·31

* Ann. de Chim. et de Phys. xxxix. 10. † Jour. de Pharmacie, xxiii. 30.

Making the atomic weight of paramaleic acid 6·31. The true weight is obviously 6·125.

This is one of the most extraordinary examples of isomerism at present known. In most other isomeric bodies there is a difference in the proportion of water in combination with the two isomeric bodies. But in the present case no such difference exists.

Some years ago, M. Winckler found in the juice of the *fumaria officinalis*, a salt in small grains, composed of lime, and a peculiar acid, to which he gave the name of *fumaric*. He sent a quantity of this acid to M. Liebig, who requested M. Demorçay to subject it to analysis. The result of the analysis showed it to be identical with the paramaleic acid of Pelouze; and, upon comparing the two acids together, they were found to agree in every respect.*

Still more lately, M. Schödler has ascertained that the *lichenic acid* discovered by Pfaff in the *cetraria Islandica*, or islandic moss, is also identical in its composition and character with the paramaleic acid.† According to Schödler's analysis, lichenic acid is composed of

Carbon	41·29
Hydrogen	3·44
Oxygen	55·37
	100·00

Numbers sensibly the same as those of Pelouze.

Thus it appears that paramaleic acid is not merely a product of decomposition by heat, since it is formed in *fumaria officinalis* and *cetraria Islandica*, by the common processes of vegetation.

SECT. IV.—OF CITRIC ACID.

This acid has been described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 71), and its composition stated. It has been recently examined by Berzelius and M. Jules Gay-Lussac, and found exact. We may then consider it as established that its constituents are

4 atoms carbon . . .	=3
2 atoms hydrogen . . .	=0·25
4 atoms oxygen . . .	=4
	7·25

But the salts formed by means of this acid have been lately examined by Berzelius, who has shown them to have a much greater tendency to combine with additional portions either of acid or base than any other genus of salts hitherto examined.‡ It is of importance to state the results obtained by this distinguished chemist.

1. *Citrate of soda.* When this salt, whether in crystals or powder, is dried *in vacuo* over sulphuric acid, and then exposed to the temperature of 212°, it loses 17½ per cent. of water of crystallization. It undergoes no further loss of weight though heated to 230°. If the salt, after being thus heated, be exposed to the temperature of

* Ann. de Chim. et de Phys. lvi. 429. † Ann. der Pharm. xvii. 148.
‡ Ann. de Chim. et de Phys. lii. 424.

392°, it loses 12·3 per cent. of its weight, without assuming a brown colour or giving out empyreumatic vapours. If we now dissolve it in water and evaporate to dryness, we obtain the original 100 of citrate of soda quite unaltered.

It is pretty evident from this statement that the citrate of soda dried over sulphuric acid is composed of

1 atom citric acid . . .	7·25
1 atom soda	4
4 atoms water . . .	4·5
	15·75

When heated to 212° it loses $2\frac{1}{2}$ atoms water, and the remaining $1\frac{1}{2}$ atoms, which are more intimately combined, are driven of by a heat of 392°. These atomic numbers when applied to 100 parts of the salt would give

Anhydrous salt . . .	71·44
Water driven off at 212° .	17·85
Do. at 392° .	10·71
	100·00

Now the numbers actually found by Berzelius were

Anhydrous salt . . .	72·36
Water driven off at 212° .	17·5
Do. at 392° .	10·14
	100·00

We have only to admit, what is surely very likely, that 0·92 per cent. of the water of crystallization in the salt was disengaged while it was drying *in vacuo* over sulphuric acid, to make results, which appeared to the experimenter so anomalous, coincide perfectly with numerous other phenomena of a similar nature.

2. *Citrate of lead.* When an alcoholic solution of citric acid is poured into a solution of acetate of lead, we obtain a citrate of lead very nearly neutral. Berzelius obtained a supercitrate of lead by boiling citrate of lead in dilute nitric acid. The salt thus formed he found to be a sesquicitrate composed of

$1\frac{1}{2}$ atoms citric acid . .	10·875
1 atom oxide of lead . .	14
1 atom water . . .	1·125
	26

To form a subcitrate of lead he digested citrate of lead still moist in close vessels with very weak caustic ammonia. The salt was composed of

1 atom citric acid . . .	7·25
$1\frac{1}{3}$ atom oxide of lead . .	18·66
	25·91

I think it very probable that this was rather a mixture of 1 atom citrate of lead with $\frac{1}{3}$ atom oxide of lead than a chemical compound.

When citrate of lead, still moist, was digested with subacetate of lead, he obtained a bicitrate composed of

2 atoms citric acid . . .	14·5
1 atom oxide of lead . .	14
	28·5

Jules Gay-Lussac obtained the following compounds of citric acid and oxide of lead:—

1. $3\overline{C} + PbO$*
2. $3\overline{C} + 4PbO$
3. $\overline{C} + 2PbO$

3. *Citrate of barytes.* Neutral citrate of barytes is composed of

1 atom citric acid . . .	7·25
1 atom barytes . . .	9·5
2 atoms water . . .	2·25
	19

It loses all its water when heated to 212°.

Barytes forms two supersalts with citric acid. One of them seems to be a bicitrate. It dissolves readily in water, and, when dried, assumes the appearance of gum. The other salt is composed, according to Berzelius (who however does not give us the analysis), of

1·25 atoms citric acid . .	9·375
1 atom barytes . .	9·5
4 atoms water . . .	4·5
	23·375

J. Gay-Lussac obtained $2(\overline{C}+BaO)+(3\overline{C}+2BaO)$†

4. *Citrate of Lime.* The neutral citrate of lime is composed of

1 atom citric acid . . .	7·25
1 atom lime	3·5
1 atom water	1·125
	11·875

The super and subsalts resemble those of barytes in their composition.

Jules Gay-Lussac obtained‡

Citrate of silver . .	$\overline{C}+AgO$
Citrate of copper . .	$3\overline{C}+4CuO$

The anomalies in the composition of these salts, and which appeared so extraordinary to Berzelius, are owing, as Mr. Richardson has shown, to the different quantity of water contained in the two salts.

* $\overline{C}$ means an atom of citric acid. † Ann. der Pharmacie, v. 136. ‡ Ibid.

§ Berzelius's experiments on citric acid were published in the Kong Vetensk. Acad. Handl. for 1832. A translation of this long paper was inserted into Poggendorf's Annalen, xxvi. 281.

M. Tilloy, apothecary at Dijon, has suggested an economical mode of extracting citric acid from currants, which deserves to be noticed here :—

Pound the currants, and cause them to ferment. When the fermentation is over, distil the mass to separate the alcohol which it contains. While the liquid is still hot, saturate it with chalk, and wash the citrate of lime with water, and finally subject it to pressure. This citrate being coloured and mixed with malate of lime, is mixed with water, and reduced to the consistence of a syrup. It is then decomposed by sulphuric acid diluted with twice its weight of water. The citric acid, thus obtained, is saturated again with carbonate of lime, well washed, subjected to the press, and treated as before with sulphuric acid. The clear liquid, thus obtained, is rendered colourless by agitation with animal charcoal, and finally evaporated. When brought to the requisite consistency, it is set to crystallize in stoves, having a temperature from 77° to 86°. The crystals obtained are coloured; but they may be washed in the same way as sugar is clayed. They are then redissolved and crystallized anew. By this process M. Tilloy assures us that citric acid may be obtained at one-fourth of the price at which it is sold in France.*

When citric acid is kept melted at a temperature of 392°, it is converted into a new acid, possessing peculiar properties. There seems to be little doubt that this new acid is the same with the *aconitic* acid of Dahlström. The formula for this acid seems to be C^4 H O^3†

The action of heat on citric acid has been lately examined by M. Robiquet.‡ The results which he obtained are very interesting.

The acid was dried and pulverized before it was put into the retort. When heated it melted at 302°. A clear liquid immediately distilled over, and, at the same time, carbonic oxide gas was extricated. Crystalline needles attached themselves to the vault of the retort, which disappeared as the distillation proceeded. Along with the carbonic oxide there passes carbonic acid gas, and as the former diminishes, the latter increases.

The colourless liquid that passes over consists of water, holding in solution *acetone* and pyrocitric acid. The thermometer keeps long at 320°. It gradually rises to 347°. At that temperature the distillation is very rapid. At last drops of oil begin to pass, and at 410° nothing passes over but this colourless oil. At 464° the oil begins to assume a yellow colour. When the heat rises to 518°, the residue in the retort swells up, and, if we still increase the heat, fuliginous vapours appear, and a brown empyreumatic oil condenses. At last, we obtain a yellow matter of the consistence of lard.

The oil yields crystals of pyrocitric acid. It contains no water, and does not acquire solidity by heat. It is anhydrous *citricic* acid.

* Ann. de Chim. et de Phys. xxxix. 222.
† Berzelius' Jahres-Bericht, für 1835, p. 270.
‡ Ann. de Chim. et de Phys. lxv. 68.

SECTION V.—OF PYROCITRIC ACID.

When the *Chemistry of Inorganic Bodies* was published, the only attempt to determine the composition of this acid was that made by M. Lassaigne, to whom we owe its discovery. He analyzed some of its salts, and gave an ultimate analysis of it by means of oxide of copper. But as these results did not correspond with each other, it was clear that the analyses could not be correct. Since that time a most elaborate set of experiments to determine its constitution and atomic weight has been made by M. Dumas.*

When citric acid is distilled in a retort, it passes over almost entirely into the receiver. A small residue of charcoal only remains, which is constant in whatever way the distillation is carried on. The liquid in the receiver has at first an oily appearance, but the oil speedily disappears, the whole being converted into water, pyrocitric acid, and a volatile spirituous liquid, having some resemblance to acetone.

Pyrocitric acid does not easily crystallize. When a hot concentrated solution is allowed to cool, the acid separates in a white mass, consisting of needles interlaced together. M. Dumas, in order to determine the atomic weight of this acid, formed a quantity of very pure pyrocitrate of lead, which, after being washed and dried at the temperature of 356°, was considered as anhydrous. 100 parts of this salt formed 90·1 parts of sulphate of lead, equivalent to 66·39 of oxide of lead. Hence the pyrocitrate was composed of

Pyrocitric acid .	33·61 or	7·08
Oxide of lead . .	66·39	14
	100·00	

According to this experiment, which was repeated five times, with results closely approaching each other, the atomic weight of pyrocitric acid is 7·08, which comes within 1 per cent of 7.

Dumas subjected the pyrocitric acid in pyrocitrate of lead to an ultimate analysis by means of oxide of copper, and obtained

Carbon	54·30 or 5 atoms	=3·75 or	per cent 53·57
Hydrogen	3·52 or 2 atoms	=0·25	— — 3·57
Oxygen	42·18 or 3 atoms	=3·00	— — 42·86
	100	7·	100

Showing that 7 is the true atomic weight of this acid, and that its ultimate constituents are as represented. Before any conclusions could be drawn respecting the nature of the decomposition which citric acid undergoes when distilled, it would be necessary to know the composition and quantity of the spirit formed during the process.

* Ann. de Chim. et de Phys. lii. 295.

SECTION VI.—OF TARTARIC ACID.

There is nothing to add to the account of this acid given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 64).

SECTION VII.—OF PYROTARTARIC ACID.

This acid was made known to chemists in 1834. M. Pelouze obtained it by exposing tartaric acid to heat in a retort.*

When tartaric acid in a retort, is kept at the temperature of 374°, a liquid passes into the receiver, which yields, when evaporated, pure crystals of *pyrotartaric acid.* But this process is so very tedious, that it is better to distil at a temperature between 392° and 572°. The liquid that passes over is to be put into a retort and distilled to the consistence of a syrup. We must then change the receiver, and continue the distillation to dryness. The pyrotartaric acid is contained in this last liquid. When we surround it with a freezing mixture of snow and salt, or leave it to evaporate spontaneously, *in vacuo*, over sulphuric acid, yellow crystals are deposited. Dry these between folds of blotting paper, dissolve them in water, and agitate the boiling solution with animal charcoal, then crystallize. The crystals constitute pyrotartaric acid in a state of purity.†

Pyrotartaric acid, thus obtained is in white crystals, which have an exceedingly sour taste, but no smell; and are very soluble in water and alcohol. When heated to 212° the acid melts, and it boils at 370°. This being very near the point of decomposition, it is difficult to volatilize it without residue.

The concentrated solution of this acid does not render lime, barytes, or strontian water turbid. When dropt into diacetate of lead, a copious curdy precipitate falls, which is insoluble in water, but soluble in an excess of diacetate of lead, and in an excess of pyrotartaric acid. Acetate and nitrate of lead are not precipitated by it.

The salts of mercury, the sulphated peroxide of iron, the salts of lime, and barytes, and the sulphates of zinc, manganese and copper are not precipitated by uncombined pyrotartaric acid.

It forms with potash a very soluble, deliquescent, and difficultly crystallizable salt. The addition of an excess of acid does not precipitate a bisalt, as happens with tartaric acid. When this salt is dropt into a solution of protonitrate of mercury, a copious white precipitate falls, and with persulphate of iron, it forms a yellow precipitate, soluble in about 200 times its weight of water. With sulphate of copper it occasions a green precipitate, which is soluble in about the same quantity of water. No immediate precipitate appears when pyrotartrate of potash is mixed with acetate of lead. But after an inter-

* Ann. de Chim. et de Phys. lvi. 297.

†This acid may be obtained also by distilling cream of tartar in a retort. See the experiments of the Athenian, Alexandros Polaiologu Weniselos, in Ann. der Pharm. xv. 147.

val of some minutes or hours, the liquid begins to get muddy, and to deposit a white flocky precipitate of pyrotartrate of lead. When dropt into subacetate of lead, an immediate precipitate falls.

To determine the atomic weight of this acid, M. Pelouze analyzed the pyrotartrate of lead, and found it composed of

Pyrotartaric acid .	268·84 or 7·19
Oxide of lead . .	523·16 or 14
	792·00

From this analysis, its atomic weight appears to be 7·19; less than that of tartaric acid, as might have been expected, from the mode of its formation.

A mean of two analyses of pyrotartaric acid dried, *in vacuo*, over sulphuric acid by means of oxide of copper, gave

Carbon	45·22 or 5 atoms =	3·75 or	per cent. 45·45
Hydrogen	6·19 or 4 atoms =	0·50	— — 6·06
Oxygen	48·59 or 4 atoms =	4·00	— — 48·49
		8·25	100·00

But this analysis gives the atomic weight of pyrotartaric acid 8·25, while the analysis of pyrotartrate of lead gives it 7·19. It is obvious from this, that when pyrotartaric acid is dried, *in vacuo*, over sulphuric acid, it still retains an atom of water; and that the true constituents, supposing this atom abstracted, are

5 atoms carbon . . .	= 3·75
3 atoms hydrogen . .	= 0·375
3 atoms oxygen . .	= 3·00
	7·125

So that its true atomic weight is 7·125.

We cannot, at present, explain in what way pyrotartaric acid is derived from tartaric. Two atoms of tartaric acid are

$C^8\ H^4\ O^{10}$

and might be resolved into

1 atom pyrotartaric acid .	$C^5\ H^3\ O^3$
1 atom water . .	$H\ O$
3 atoms carbonic acid .	$C^3\ O^6$
	$C^8\ H^4\ O^{10}$

But from M. Pelouze's description, the decomposition seems to be complicated.

Some of the pyrotartrates have been examined by Weniselos.*

1. *Bipyrotartrate of ammonia* crystallizes in fine rhomboids, having their summits truncated. It is very soluble in water, is not altered by exposure to the atmosphere, and reacts strongly as an acid.

2. *Bipyrotartrate of potash* crystallizes in large rhomboids. The

* Ann. der Pharm. xv. 150.

crystals are easily soluble in water, not altered by exposure to the atmosphere. The solution gives a fine white precipitate with nitrate of silver; with sulphate of copper a blue precipitate, which is insoluble in water; with nitrate of mercury a white precipitate.

3. *Bipyrotartrate of soda* does not crystallize so readily as the preceding salts, but it assumes the same form with the potash salt. It dissolves readily in water.

4. Barytes forms with pyrotartaric acid, star-shaped crystals, easily soluble in water, and not altered by exposure to the atmosphere.

5. The salt of lime is a crystalline powder, difficultly soluble in water.

6. *Pyrotartrate of copper* is nearly insoluble in water.

7. When oxide or carbonate of lead, is dissolved in pyrotartaric acid, two salts are formed, one soluble and the other insoluble in water, and which therefore may be separated by the filter. When bipyrotartrate of potash is decomposed by nitrate of lead, no precipitate appears at first; but after some days fine needles of bipyrotartrate of lead are deposited on the sides of the glass. They are slightly soluble in water.

When racemic acid is distilled, it yields an acid identical with pyrotartaric acid.

SECTION VIII.—OF PYRUVIC ACID.

M. Pelouze observed, that when tartaric or racemic acid is distilled in a retort, besides *pyrotartaric* acid, another acid was formed, which he considered as acetic acid. It was examined by Berzelius in 1835, and found to be a new acid, which he has distinguished by the name of *pyruvic acid.**

To obtain it we have only to distil tartaric or racemic acid at the temperature of 392°, and rectify the produce of the distillation, which has a yellowish colour, over the vapour bath. The first half that comes over in this second distillation must be kept separate, because it contains some acetic acid. The last half contains the pyruvic acid.

It is a yellowish, somewhat thick liquid, having a weak smell similar to that of a mixture of acetic and muriatic acids. Its taste is acid and hot; its specific gravity 1·25. It does not crystallize, though cooled down to 23°. It undergoes a slight decomposition every time it is distilled; this is the reason of its yellow colour; but the quantity of foreign matter is so small, that the liquid evaporates spontaneously, leaving hardly any residue.

Berzelius determined its composition by analyzing anhydrous pyruvate of silver. It was composed of

Oxide of silver	59·34 or 1 atom	= 14·5	or per cent.		59·49
Carbon .	18·36 or 6 atoms	= 4·5	—	—	18·46
Hydrogen	1·92 or 3 atoms	= 0·375	—	—	1·53
Oxygen .	20·81 or 5 atoms	= 5	—	—	20·52
		24.375			100

* Jour. der Pharmacie, xiii. 61.

Hence the composition of pyruvic acid is $C^6 H^3 O^5$.* It differs from tartaric, which is $C^4 H^2 O^5$, by an atom of bicarbohydrogen; while it contains 1 atom of carbon and 2 of oxygen, constituting an atom of carbonic acid more than pyrotartaric acid.

With the bases it forms a set of salts, which, when in crystals, give to the finger drawn over them the same sensation as talc. They crystallize only when they are prepared cold. When their solution is heated, and they are then evaporated, *in vacuo*, over sulphuric acid, they assume the appearance of gum. Concentrated sulphuric acid decomposes the pyruvates with difficulty. No smell is observed when the mixture is cold. When heat is applied the mass becomes black, and a smell like that of muriatic acid is observed. We cannot in this way obtain concentrated pyruvic acid.

Pyruvate of potash is deliquescent; that of soda crystallizes in large prisms. Pyruvate of ammonia is deliquescent, that of lithia is but little soluble, and crystallizes in grains; that of barytes crystallizes in scales. It contains 1 atom of water, which it loses at 212°. Pyruvate of strontian is in small grains, but little soluble in cold, but much more so in hot water; pyruvate of lime forms a crust in grains. When dissolved in cold water and evaporated, it assumes the appearance of gum. Alumina, glucina, and yttria, form neutral insoluble salts, having the aspect of gum, and subsalts in the form of flocks. Pyruvates of zinc, iron, manganese, nickel, and cobalt, are little soluble, and have the form of grains, which are deposited as soon as the solution is saturated. They contain three atoms of water.

Zinc and iron dissolve in pyruvic acid, giving out hydrogen. Pyruvate of lead is precipitated in a white crystalline powder. It is little soluble in water, but dissolves in an excess of acid, and assumes the appearance of gum. When heated to 212° it becomes yellow. It contains an atom of water, which it does not lose at 248°. But it becomes orange. Pyruvate of silver is snow white, and little soluble. It contains no water. When distilled it gives out acetic acid, mixed with a little pyruvic acid, and leaves a residue of silver and charcoal.

SECTION IX.—OF RACEMIC ACID.

This acid has been described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 69), under the name of *vinic acid*. But the term *racemic acid*, given it by M. Gay-Lussac in 1828, is better, because in some parts of the continent *vinic acid* is the name given to tartaric acid.†

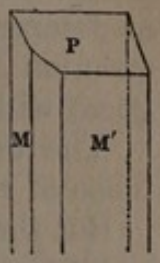
I stated, from some imperfect experiments which I had made on a small quantity of this acid, given me by M. Kestner, the original discoverer of it, my suspicion that its atomic weight was 8·5. But having been since supplied with a large quantity of racemic acid, by

* Poggendorf's Annalen, xxxvi. 10.

† The German name for tartaric acid is *weinsäure*, meaning *wine* or *vinic acid*.

the liberality of Mr Edmond Thomson of Manchester, I was enabled to make a pretty full set of experiments on its combinations. These experiments, after lying by me for two or three years, were published, in 1835, in the *Records of General Science* (ii. 97, 161, 241).* These experiments leave no doubt that tartaric and racemic acids are *isomeric;* yet the operations of the two are very different.

They both form doubly oblique prisms, but in tartaric acid M on M′ is . . . 88° 30′
In racemic acid . . . . 68°
In tartaric acid P on M or M′ is . 97° 10′
In racemic acid . . . . 75°



The lustre of tartaric acid is *glossy*, that of racemic acid *silky*.

When racemic acid is heated to 150°, it loses its crystalline from, and gives out 5·59 per cent. of water. At the same temperature the crystals of tartaric acid undergo no change, and lose no weight. When the heat is increased, racemic acid undergoes no farther change till it reach the temperature of 370°, when it assumes a yellow colour, and begins to undergo decomposition. At 250° tartaric acid liquifies, and loses about 4 per cent. of its weight. By this heat its nature is altered, for it forms salts with bases quite different from tartrates.

At the temperature of 49°, 100 parts of water dissolves 14·1 parts of racemic acid crystals; while they dissolve at the same temperature 64·8 parts of tartaric acid.

When racemic acid is dropt into a solution of chloride of calcium, a copious precipitate falls; while tartaric acid occasions no immediate precipitate when added to this chloride.

But both of these acids possess the property of preventing the solution of antimony in muriatic acid from being precipitated by water.

Berzelius analyzed racemic acid, and informs us that he found its constituents the same as those of tartaric acid, namely,

4 atoms carbon . . .	=3
2 atoms hydrogen . .	=0·25
5 atoms oxygen . . .	=5
Atomic weight . .	8·25†

Now I found racemate of lead composed of

Racemic acid . . .	8·206
Oxide of lead . . .	14

* From a paper by Berzelius on racemic acid, it appears that M. Walchner has also examined the *racemates*, and that his experiments have been inserted in the third edition of L. Gmelin's *Handbuch der theoretischen Chemie*. Not having seen that edition, I do not know how far Walchner's experiments agree with my own.

† Annales de Chim. et de Phys. xlvi. 128.

And racemate of potash

Racemic acid . . .	8·224
Potash	6

And racemic acid crystals of

Racemic acid . .	8·25 or 8·202
Water . . .	2·263 or 2·25

These numbers come so near 8·25, the atomic weight of racemic acid, as determined by Berzelius, that there can be no doubt that its constitution is the same (so far as the number of ultimate elements goes) with that of tartaric acid.

The crystals of tartaric acid contain only 1 atom water, while those of racemic acid contain 2 atoms.

But the difference between the characters of these two acids will be better understood if we compare together some of the principal tartrates and racemates.

1. *Racemate of ammonia.* This salt is best formed by adding racemic acid to a solution of carbonate of ammonia, till all effervescence is at an end. The crystals are beautiful, consisting of doubly oblique prisms, whose faces are inclined at an angle of 94° 45′. They effloresce slightly in the atmosphere, and have a specific gravity of 1·639.

Taste saline, and cooling. 100 parts of water at 60° dissolve 14·58 of this salt. Insoluble in alcohol, or almost so. Its constituents are

1 atom racemic acid . .	8·25
1 atom ammonia . . .	2·125
½ atom water . . .	0·5625
	10·9375

When ammonia or its carbonate is cautiously dropt into a solution of racemic acid, biracemate falls in bulky flocks, consisting of minute crystals.

Tartrate of ammonia. The taste of this salt is saline, very like that of sal ammoniac. It usually forms gritty crystals; but it may be obtained in large transparent four-sided prisms, the base of which meets the adjacent faces at angles of 120° and 60°. In general all the edges are replaced by tangent planes, making an eight-sided prism, with angles of 135°. At 55°, 100 parts of water dissolve 60·03 parts of it, so that it is at least four times as soluble as racemate of ammonia. Its constituents are

1 atom tartaric acid . .	8·25
1 atom ammonia . . .	2·125
1 atom water	1·125
	11·5

Thus it differs from racemate of ammonia, by containing twice as much water of crystallization, by being much more soluble in water, and by the shape of its crystals being different.

2. *Racemate of potash.* It crystallizes in large transparent crystals,

which are right oblique four-sided prisms, whose faces are inclined at angles of 120° and 60°. The edges of 60° are usually replaced by planes, making unequal angles with the adjacent faces. The terminal edges are almost always replaced by tangent planes, constituting a four-sided pyramid, with very unequal faces.

Taste saline, harsh, and bitter. Specific gravity 2·08. At 55° 100 parts of water dissolve 112·59 of this salt. It is not sensibly soluble in alcohol. It is composed of

1 atom racemic acid . .	8·25
1 atom potash . . .	6
1 atom water . . .	1·25
	15·375

In general the water amounts to 1·32; the 0·195 (about $\frac{1}{5}$ of an atom) of excess is doubtless lodged mechanically between the plates of the crystals.

Tartrate of potash. Crystals large, right oblique transparent prisms, the faces of which are inclined at angles of 89° 30′ and 90° 30′. The obtuse edges are generally replaced by tangent planes.

Taste saline, and unpleasantly bitter. Specific gravity 2·140. Dissolves at 50° in its own weight of water, according to Wenzel. Its constituents are

1 atom tartaric acid . .	8·25
1 atom potash . . .	6·00
$2\frac{1}{2}$ atoms water . . .	2·8125
	17·0625

3. *Biracemate of potash.* Obtained by mixing a solution of 214 grains of racemic acid crystals with that of 87·5 grains of anhydrous carbonate of potash.

A white crystalline powder, reddening vegetable blues, and having an acidulous taste. Specific gravity 2·555. At 55°, 100 parts of water dissolve 0·57, and at 108°, 1·12 of the salt. Crystals very irregular; but seem to be six or four-sided prisms and pyramids. It seems anhydrous, and is composed of

2 atoms racemic acid . .	16·5
1 atom potash . . .	6
	22·5

Bitartrate of potash is less soluble in water, and contains 2 atoms of water in its crystals.

4. *Racemate of soda.* Crystallizes in small rectangular prisms. Taste saline, and bitter. Sp. gr. 1·511. Not sensibly soluble in alcohol. 100 parts of water at 63° dissolve 31·73 parts of it. When heated it does not melt like racemate of potash, but becomes brown, froths and burns with flame, leaving carbonate of soda, coloured by charcoal. It is anhydrous, or contains only $\frac{1}{6}$ of an atom of water. Its constituents are

1 atom racemic acid . .	8·25
1 atom soda	4
	12·25
Water	0·177
	12·427

Tartrate of soda. Crystals oblique, four-sided prisms. Taste saline, and bitter. Sp. gr. 1·980. 100 parts of water at 61° dissolve 56·37 parts of it. Not sensibly soluble in alcohol. When heated it fuses, but soon loses its water of crystallization, and falls to powder. Composed of

1 atom tartaric acid . .	8·25
1 atom soda . . .	4
$2\frac{1}{2}$ atoms water . . .	2·8125
	15·0625

5. *Racemate of barytes.* A tasteless powder, having a specific gravity of 2·615. 100 parts of water at 122° dissolves 0·034 of it. Not sensibly soluble in alcohol. Does not melt when heated. Composed of

1 atom racemic acid . .	8·25
1 atom barytes . . .	9·5
2 atoms water . . .	2·25
	20

Tartrate of barytes. A tasteless powder, having a specific gravity of 2·524. 100 parts of water at 63° dissolves 0·133 of it. When heated it burns with flame, which is not the case with the racemate. It loses no weight unless the heat be high enough to act upon the acid. It is anhydrous, and composed of

1 atom tartaric acid . .	8·28
1 atom barytes . . .	9·5
	17·78

6. *Racemate of strontian.* A white, soft, tasteless powder, very like magnesia alba. Sp. gr. 1·409. 100 parts of water at 135° dissolve 0·104 of it. When heated it gives off acetic acid, blackens, burns, and leaves carbonate of strontian quite white. Its constituents are

1 atom racemic acid . .	8·25
1 atom strontian . . .	6·5
4 atoms water . . .	4·5
	19·25

Tartrate of Strontian. Crystals right oblique prisms, faces meeting at angles of 113° 20′ and 66° 40′, transparent, and having a vitreous lustre. Tasteless. Sp. gr. 1·837. 100 parts of water at 170°, dissolves 0·67 of it. When heated, it gives out acetic acid,

swells up like a cauliflower, burns with flame, and leaves carbonate of strontian. It is composed of

1 atom tartaric acid . .	8·25
1 atom strontian . . .	6·5
3 atoms water . . .	3·375
	18·125

7. *Racemate of lime.* A white tasteless powder. While moist, the particles adhere together like clay, and have the property of sticking to every thing with which they come in contact. Sp. gr. 1·542. 100 parts of water at 58° dissolves 0·029 of it. It is rather more soluble in boiling water. At 450° assumes a brownish tinge. At a higher temperature it burns like tinder, and assumes the appearance of a liquid boiling. Its constituents seem to be

1 atom racemic acid . .	8·25
1 atom lime	3·5
5 atoms water . . .	5·625
	17·375

Tartrate of lime. A white tasteless powder, having the sp. gravity of 1·9009. 100 parts of water at 58° dissolves 0·013 of it, while 100 of boiling water dissolves 0·17. When heated nearly to redness, it burns like tinder, and leaves carbonate of lime.

Its composition seems to be exactly the same as that of racemate of lime. But as this is scarcely the case with any other pair of these salts, the subject still seems to deserve further investigation.

8. *Racemate of magnesia.* A tasteless powder having a sp. gravity of 1·980. 100 parts of water at 64° dissolves 0·35 of it. When heated, it burns like tinder, and leaves magnesia. Its constituents are

1 atom racemic acid . .	8·25
1 atom magnesia . . .	2·5
2 atoms water . .	2·25
	13

Magnesia alba may be dissolved in racemic acid, and by washing the salt we get rid of almost all excess of acid. The racemate thus formed has a specific gravity of 1·32, and is composed of

1 atom racemic acid . .	8·25
1 atom magnesia . . .	2·5
$4\frac{1}{2}$ atoms water . . .	5·0025
	15·7525

Tartrate of magnesia. A snow-white powder consisting of very minute crystals. Nearly tasteless, but giving, when kept in the mouth, a slight impression of bitterness. Sp. gr. 1·960. 100 parts boiling water dissolves 0·6 of it. Cold water dissolves nearly as much. Its constituents seem to be

1 atom tartaric acid . .	8·25
1 atom magnesia . . .	2·5
2 atoms water . . .	2·25
	13

or the same as that of one of the racemates.

9. *Racemate of alumina.* Racemic acid does not dissolve alumina, but, by digestion, converts it into a bulky white powder, tasteless and insoluble in water, and composed of

1 atom racemic acid . .	8·25
$1\frac{2}{3}$ atom alumina . . .	3·141
2 atoms water . . .	2·25
	13·641

But the two-thirds of the atom of alumina may have been only mechanically mixed with the salt.

Tartaric acid dissolves hydrated alumina with ease, and forms a viscid transparent matter like gum arabic. It is tasteless and neutral and composed of

1 atom tartaric acid . .	8·25
1 atom alumina . . .	2·25
1 atom water	1·125
	11·625

10. *Racemate of iron.* Racemic acid dissolves iron with evolution of hydrogen gas, and soft white needles of racemate of iron are deposited. But it is most easily obtained by mixing solutions of sulphate of iron and racemate of soda in the atomic proportions.

A white or greenish crystalline matter having an inky taste. 100 parts of boiling water dissolves 0·4 of it, and water at 58° dissolves nearly as much. When heated to 400, it catches fire and burns like tinder. It is composed of

1 atom racemic acid . .	8.25
1 atom protoxide of iron . .	4·50
1 atom water	1·125
	13·875

Peroxide of iron combines with racemic acid, and forms a red-coloured salt having a harsh and astringent taste.

11. *Racemate of manganese.* It may be formed by digesting carbonate of manganese in a solution of racemic acid. The carbonate gradually assumes a flesh-red colour, being converted into racemate.

When this salt, after being washed and dried, is put into the mouth it gives a slight impression of sweetness. Sp. gr. 1·960. 100 parts of water at 55° dissolve 0·048, and at 212° 0·14 of this salt. Its constituents are

1 atom racemic acid . .	8·25
1 atom protoxide of manganese	4·5
2 atoms water . . .	2·25
	15

Tartrate of manganese crystallizes in fine flesh-red four-sided prisms, apparently rectangular. This salt is more soluble in water, but its composition is the same as that of the racemate.

12. *Racemate of nickel.* A fine green powder, tasteless, but leaving a disagreeable impression in the mouth. Sp. gr. 1·76176. 100 parts of water at 57° dissolves 0·056, and 100 parts of boiling water 1·724 of it. The solution has a fine green colour, and, when cooled, slowly deposits the salt in small crystals, which seem to be flat rectangular prisms. Its constituents seem to be

1 atom racemic acid . .	8·25
1 atom oxide of nickel . .	4·25
2 atoms water . . .	2·25
	14·75

13. *Racemate of cobalt.* Colour a fine deep violet. It is tasteless, yet leaves a disagreeable impression in the mouth. Sp. gr. 1·769. 100 parts of water at 60°, dissolves 0·118, and 100 parts of boiling water 0·42 of it. The solution has a pretty deep red colour; but it does not yield crystals. Its constituents are

1 atom racemic acid . .	8·25
1 atom oxide of cobalt . .	4·25
5 atoms water . . .	5·625
	18·125

14. *Racemate of zinc.* A soft white powder, having a slight shade of buff. Taste weak, but similar to that of the salts of zinc. Sp. gr. 1·980. 100 parts of water at 60° dissolve 1·067, and 100 parts of boiling water 2·58 of it. When the solution is cooled slowly, it deposits beautiful silky crystals. They are flat four-sided prisms, having some resemblance to benzoic acid. Its constituents are

1 atom racemic acid . .	8·25
1 atom oxide of zinc . .	5·25
$4\frac{1}{2}$ atoms water . . .	3·9375
	17·4375

15. *Racemate of cadmium.* A beautiful white salt crystallized in small needles. Tasteless. Lustre satiny. Sp. gr. 2·64. 100 parts of water at 52°, dissolve 0·105, and at 212°, 0·206 of it. Its constituents are

1 atom racemic acid . .	8·25
1 atom oxide of cadmium .	8
$4\frac{1}{2}$ atoms water . . .	5·0625
	21·3125

16. *Racemate of lead.* A white crystalline tasteless powder. Sp. gr. 3·168. 100 parts of water at 60° dissolves 0·021, and at 212° 0·088 of it. Its constituents are

1 atom racemic acid . .	8·25
1 atom oxide of lead . .	14
$4\frac{2}{3}$ atoms water . . .	5·245
	27·495

When exposed to a heat of 100° it loses all its water except $1\frac{1}{2}$ atoms. Hence it is probable that the chemically combined water is only $1\frac{1}{2}$ atom. This would reduce the atomic weight of the salt to 23·9375.

The tartrate of lead is an anhydrous salt.

17. *Racemated suboxide of mercury.* This salt precipitates in the state of a white powder when solutions of nitrated suboxide of mercury and racemate of soda are mixed together in atomic proportions. It is a white powder having a slight mercurial taste. Sp. gr. 2·525. 100 parts of water at 195° dissolve 0·0296 of it.

It is anhydrous and composed of

Racemic acid . .	8·25
Suboxide of mercury . .	26
	34·25

18. *Racemate of silver.* This salt precipitates when nitrate of silver and racemate of soda are mixed in atomic proportions. It is a white powder, but becomes black when heated. Sp. gr. 3·168. 100 parts of water at 100° dissolves 0·268 of it. Has a slight taste similar to that of the other salts of silver. Its constituents are

1 atom racemic acid . .	8·25
1 atom oxide of silver . .	14·50
$\frac{1}{2}$ atom water	0·5625
	23·3125

19. *Potash racemate of antimony.* This salt, which is analogous to tartar emetic, may be formed by boiling together biracemate of potash and glass of antimony.

White. Crystallizes in four-sided prisms. Sp. gr. 2·589. 100 parts of water at 48° dissolve 4·11, and at 130°, 14 of it. Like tartar emetic it possesses emetic qualities. Indeed, when administered, it cannot, as far as its action goes, be distinguished from tartar emetic. When heated, it blackens and burns like tinder. Its constituents are

2 atoms racemic acid . .	16·5
1 atom potash . . .	6
2 atoms protoxide of antimony .	18
3 atoms water . . .	3·375
	43·875

Tartar emetic contains only two atoms water.

SECT. X.—OF OXALHYDRIC ACID.

Scheele observed, that when dilute nitric acid was made to act upon mucous bodies under peculiar circumstances, an acid was formed, which he could not crystallize, and which possessing several properties in common with the malic acid, which he had extracted from various fruits, he considered as identical with that acid. Fourcroy and Vauquelin many years after repeated the experiments of Scheele, and drew from them the same conclusions that he had done. The incrystallizable acid obtained, when nitric acid is made to act upon sugar, gum, and various other bodies, was generally admitted by chemists, to be the same with the malic acid of fruits.

Trommsdorf seems to have been the first chemist who thought of examining minutely the characters of this artificial acid. He found them different from those of malic acid, and therefore announced that the artificial acid was a peculiar acid *sui generis.**

In the year 1831, M. T. Guerin Varry made a set of experiments to determine the point, and finding the artificial acid to possess peculiar properties, he determined its composition, and distinguished it by the name of *oxalhydric acid.* He drew up a minute account of the characters of this acid, and of the salts which it forms.† It will be proper to state the most important of the facts which he has ascertained in this place. The oxalhydric acid is noticed in the work on the *Chemistry of Inorganic Bodies* (ii. 80), as probably constituting a new and peculiar acid, in consequence of the experiments of Vogel, published as long ago, as 1819.‡ The statements of Vogel have been fully confirmed by the experiments of M. Guerin Varry, of which I shall now give the substance.

M. Guerin prepared the oxalhydric acid which he examined by the following process. 1 part of gumarabic, and 2 parts of nitric acid diluted with half its weight of water, were put into a retort capable of holding four times the bulk of the substances introduced. The retort was attached to a globular and tubulated receiver. A moderate heat was applied till the gum was all dissolved. When nitrous vapours began to appear, the retort was removed from the fire. When the disengagement of nitrous gas was at an end, the liquid was kept gently boiling for an hour. It was then diluted with four times its weight of water, and saturated with ammonia. Nitrate of lime was dropt into the liquid, to throw down the oxalic acid formed during the process. The reddish yellow liquid being filtered, was precipitated by acetate of lead. The oxalhydrate of lead which fell was collected on a filter and thoroughly washed with water. It was then mixed with water, and the lead separated from the acid by a current of sulphuretted hydrogen gas, or it may be separated by sulphuric acid diluted with six times its weight of water.

Oxalhydric acid thus obtained was yellow. It was evaporated by a gentle heat, to the consistence of a syrup, it was then saturated

* Ann. de Chim. et de Phys. liv. 320. † Ibid. xlix. 282, and lii. 318.
‡ Gilbert's Annalen, lxi. 233.

with ammonia, and evaporated till it began to crystallize. The crystals were dissolved in water, and deprived of their colour by animal charcoal. The salt was then decomposed by acetate of lead, and the lead separated by sulphuretted hydrogen as before. The liquid thus obtained was colourless. It was evaporated to the consistence of a syrup, and then dried, *in vacuo*, over sulphuric acid.

The acid could not be made to crystallize, but constituted a white solid matter, composed of two atoms oxalhydric acid, and 1 atom water.

Sugar or starch may be employed to form oxalhydric acid, instead of gum. 1000 parts of gum yield 2·8 parts, 1000 of starch 3·1 parts, and 1000 of sugar 3·5 parts of dry oxalhydric acid.

Oxalhydric acid has a sour taste; but is destitute of smell. Its specific gravity at 68° is 1·416. It is very deliquescent, and after having absorbed moisture from the atmosphere, its specific gravity is reduced to 1·375. It is very soluble in water and alcohol; but these solutions cannot be made to yield crystals. It is also very soluble in ether.

Lime, barytes, and strontian water are precipitated by oxalhydric acid; but the precipitates are redissolved by a slight excess of the acid. It precipitates in bulky flocks, the subacetate, acetate, and nitrate of lead. The precipitate is insoluble in cold water, and in an excess of oxalhydric acid. But it is slightly soluble in boiling water, from which it precipitates, as the liquid cools, in small scales.

When exposed to the action of heat, it is decomposed very readily, and leaves a charcoal of difficult incineration.

When heated in a tube, it leaves a residue, which when cooled without contact of air, and then projected into the atmosphere, suddenly becomes red hot in globule, leaving traces of a thick vapour.

When oxalhydric acid dissolved in water, was left for a month in a phial, with a ground stopper, it deposited crystals having the shape of those of oxalic acid, but possessing the properties of oxalhydric acid. M. Guerin who obtained them, considered them as crystals of oxalhydric acid. But M. Erdmann has since shown that they are crystals of tartaric acid.

It does not precipitate potash from a concentrated solution like tartaric acid. But it agrees with that acid in precipitating lime, barytes and strontian waters, which malic acid is unable to do.

It dissolves zinc and iron with the evolution of hydrogen gas.

The concentrated solution of oxalhydric acid may be kept for months without undergoing any sensible change; but when diluted with water, it deposits a mucilaginous matter in a few days.

When 1 part of oxalhydric acid was mixed with 3 parts of nitric acid, and left in a phial with a small opening for a month, being well agitated every day, it deposited a great number of crystals of oxalic acid, while deutoxide of azote was disengaged.

When heated with nitric acid it is converted into oxalic acid and carbonic acid.

To determine the atomic weight of oxalhydric acid, M. Guerin Varry analyzed oxalhydrate of lead, and found it composed of

Oxalhydric acid	.	40·34 or 9·466
Oxide of lead	.	59·66 or 14
		100·00

According to this analysis, the atomic weight is 9·466 or 9·5. He subjected it to an ultimate analysis by means of oxide of copper.

The following table shows the result, when he employed oxalhydrate of lead, and oxalhydrate of zinc.

	From salt of lead.	From salt of zinc.	Mean.
Carbon	31·35	33·14	32·25
Hydrogen	4·08	3·65	3·86
Oxygen	64·57	63·21	63·89
	100		

4 atoms carbon	.	= 3	or per cent 32
3 atoms hydrogen	.	= 0·375	— — 4
6 atoms oxygen	.	= 6	— — 64
		9·375	100

From this it appears that its true atomic weight is 9·375, and that it is $C^4\ H^3\ O^6$

Professor Erdmann* of Leipzig, has published a set of very careful experiments, to prove that oxalhydric acid has the same composition as tartaric acid. He says, that if a solution of this acid be exposed to spontaneous evaporation, it yields crystals of tartaric acid. Now the constituents of oxalhydric acid as determined by M. Guerin Varry are . . $C^4\ H^3\ O^6$

Tartaric acid is . $C^4\ H^2\ O^5$

H O

Thus it appears that if oxalhydric acid be deprived of an atom of water, it becomes tartaric acid. It is easy to see how the change may take place. M. Guerin has answered M. Erdmann's experiments, and affirms, that both oxalhydric acid and tartaric acid are present in the liquid.†

It was called oxalhydric acid by M. Guerin Varry, because if to two atoms of oxalic acid ($C^4\ O^6$) we add 3 atoms of hydrogen (H^3) we obtain this acid. Erdmann called it paratartaric acid, because its composition is the same as that of tartaric acid, though its properties are different.

SECTION XI.—OF MUCIC ACID.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 88), I have endeavoured to show, that mucic acid is composed of $C^6\ H^4\ O^8$. From the analysis of this acid by Berzelius, the constitution is

* Annalen der Pharm. xxi. 1. † Jour. de Pharmacie, xxiii. 416.

C^6 H^5 O^8. But M. Malaguti has shown, that in the state in which it was examined by Berzelius, it contained an atom of water, and that the true constitution of the anhydrous acid, is

6 atoms carbon	= 4·5	or per cent.	37·5
4 atoms hydrogen	= 0·5	— —	4·16
7 atoms oxygen	= 7·0	— —	58·33
	12		100*

So that the true atomic weight of this acid is 12. The analysis of Malaguti has been repeated by Liebig and Pelouze, and found correct.†

They found the mucate of silver composed of

Mucic acid . .	375·2 or 12·17
Oxide of silver . .	446·8 or 14·5

White mucic ether, discovered by M. Malaguti, was found composed of

10 atoms carbon . .	= 7·5
9 atoms hydrogen . .	= 1·125
8 atoms oxygen . .	= 8·0
	16·625

Now, if from	C^{10} H^9 O^8
we substract mucic acid . . .	C^6 H^4 O^7
there will remain	C^4 H^5 O

which corresponds with an atom of sulphuric ether. It is obvious, from this, that mucic ether is a compound of 1 atom mucic acid, and 1 atom ether.

SECTION XII.—OF PARAMUCIC ACID.

This acid, which is isomeric with mucic acid, was discovered by M. Malaguti, in 1835.‡

If we saturate boiling water with mucic acid, evaporate the solution to dryness, digest the residual matter in alcohol, and allow the alcoholic solution to evaporate spontaneously, we obtain, at first, a white flocky precipitate, and by continuing the evaporation, a crystalline crust, mixed with crystals sufficiently large, to show that they consist of rectangular plates. This matter has a much more acid taste than mucic acid. It dissolves pretty readily in cold water, 100 parts of cold water dissolve 1·359, and 100 parts of boiling water dissolve 5·8 parts of it, while the same quantity of boiling water dissolves only 1·5 of mucic acid. As mucic acid is insoluble in alcohol, it might naturally be supposed, that the acid thus obtained by means of alcohol is different from mucic acid. Yet its constituents, determined by the analysis of Malaguti, are identical. He obtained from paramucic acid, in crystals,

* Ann. de Chim. et de Phys. lxiii. 86. † Ibid. 132.
‡ Jour. de Pharm. xxi. 640.

Carbon	34·120 or 6 atoms	= 4·5	or per cent.	34·28
Hydrogen	4·866 or 5 atoms	= 0·625	— —	4·76
Oxygen	61·014 or 8 atoms	= 8·0	— —	60·96
	100	13·125		100·00

Now, this is obviously $C^6 H^4 O^7 + HO$, or a compound of 1 atom anhydrous mucic acid, and 1 atom water.

This agrees well with the paramucate of silver, which M. Malaguti found composed of

Paramucic acid .	47·65 or 13·198
Oxide of silver .	52·35 or 14·5
	100·00

The actions of paramucic acid correspond nearly with those of mucic acid; only in the same bulk of solution, we find less mucic than paramucic acid, and in consequence, the latter has more energy than the former.

If we pour a solution of common mucic acid into a solution of protonitrate of mercury, an abundant and very light white precipitate falls, and the supernatant liquid remains long muddy. When paramucic acid is substituted, there is no immediate precipitate, but gradually a heavy gritty powder falls, leaving the supernatant liquor quite transparent. The same phenomena takes place with nitrate of silver. A little mucic acid precipitates nitrate of silver, while the precipitate is abundant, immediate, and has a mucous appearance. With paramucic acid the precipitate is slow, and falls in a curdy state.

The mucates are less soluble than the corresponding paramucates, provided they have not crystallized in their aqueous solutions. The reason of this exception is, that when paramucic acid is allowed to crystallize from an aqueous solution, it is converted into mucic acid. If boiling water be saturated with paramucic acid, crystals are deposited as the solution cools; but these crystals are insoluble in alcohol, and possess all the characters of mucic acid.

If we have saturated solutions of mucic and paramucic acids in boiling water, and saturate each with soda, on allowing the solutions to cool, the salts formed are common mucates.

If we pour ammonia into two saturated boiling solutions of mucic and paramucic acids in water, small crystalline plates are precipitated from the latter while still hot, but not from the former. The paramucate of ammonia is almost insoluble in water, while the mucate is sensibly soluble in that liquid.

When paramucic acid is distilled, it yields an acid, identical with pyromucic acid. Malaguti analyzed it, and obtained

Carbon	53·37
Hydrogen	3·90
Oxygen	42·73
	100·00

Numbers agreeing very nearly with the analysis of the same acid, by Houton Labillardiere.

SECTION XIII.—OF PYROMUCIC ACID.

There is nothing to add to the account of this acid, given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 88), excepting that the formula for its composition should be (from a comparison of the analyses of Houton Labillardiere and Malaguti*)

10 atoms carbon	= 7·5	or per cent.	53·68
4 atoms hydrogen	= 0·5	— —	3·37
6 atoms oxygen	= 6	— —	42·95
	14		100

According to Boussingault, when uncombined with a base, it contains an atom of water. Hence the anhydrous acid consists of

10 atoms carbon . .	= 7·5
3 atoms hydrogen . .	= 0·375
5 atoms oxygen . .	= 5
	12·875

SECTION XIV.—OF MECONIC ACID.

Chemists are indebted to M. Robiquet for an important set of experiments on this acid, and for the discovery of *metameconic* and *pyromeconic acids*, which had been previously compounded with it.† And to M. Liebig, for an accurate analysis of *meconic* and *metameconic acids*.‡

The easiest method of procuring meconic acid from opium, is to make an infusion of opium with water, acidulated with sulphuric acid. This infusion is mixed (according to the process of Drs Robertson and Gregory) with a quantity of chloride of calcium, sufficient to throw down the sulphuric and meconic acids in combination with lime. This precipitate is washed, first with cold water, and afterwards with boiling alcohol. It is next mixed with ten times its weight of water, and heated to about 194°. We then add to it by little and little, agitating violently, a quantity of muriatic acid, sufficient to dissolve the meconate of lime, which constitutes the greater part of the precipitate. The liquid is poured upon a filter, previously washed with muriatic acid. On cooling, it deposits numerous light and brilliant crystals of bimeconate of lime. Dry these crystals by pressure between the folds of a cloth, dissolve them in hot water, and add a sufficient quantity of muriatic acid to decompose the salt. Keep the liquid for some time hot, but not raised so high as 212°. On allowing the liquid to cool, crystals of meconic acid are deposited. If these crystals, as sometimes hap-

* Jour. der Pharmacie, xxi. 641.

† Ann. de Chim. et de Phys. li. 236, and liii. 425.

‡ Ibid. liv. 26, and Annalen der Pharmacie, vii. 237; or Jour. der Pharmacie, xx. 21.

pens, are mixed with bimeconate of lime, we must repeat the treatment with muriatic acid, or separate the crystals of bimeconate, which are much lighter, by levigation.

To deprive it of its colouring matter, let it be saturated by a dilute solution of caustic potash. Dissolve the meconate of potash formed in a small quantity of hot water, let it cool, and expose the resulting magma to pressure. Dissolve and crystallize the salt anew, and finally decompose it by muriatic acid.

Meconic acid thus obtained is not altered by exposure to the air. When exposed to a temperature from 212° to 248°, it loses 21·5 per cent. of its weight. But this loss is not owing merely to the escape of water; carbonic acid is also given off, and the acid is partly converted into metameconic acid. It becomes gradually white and opaque. When once rendered as dry as possible, the process of decomposition stops; but it commences again if we add a little water.

Dry meconic acid is entirely destroyed, when the temperature is raised sufficiently high. First a peculiar acid distils over, to which the name of *pyromeconic acid* has been given. It is accompanied by a little water, and a little acetic acid, and is at first nearly colourless. After this an oil passes over, which becomes solid, and there is disengaged a little carbonic acid and inflammable gas. Towards the end of the process a few needles sublime, constituting another acid, which has not hitherto been particularly examined.

Meconic acid is soluble in four times its weight of hot water. When the solution is long boiled, it becomes gradually yellowish, then red, and at last, deep brown, at the same time, carbonic acid is disengaged, and the acid is changed into metameconic acid, which is no longer altered by the water. This change may be produced by the action of the water-bath continued for several days. The new acid precipitates during the cooling. The change goes on still better if we boil a meconate, mixed with an acid, capable of combining with its base.

Meconic acid crystallizes in white transparent scales. It is not altered by cold sulphuric or muriatic acid. Dilute nitric acid, converts it into oxalic acid.

To determine the atomic weight of meconic acid, Liebig* analyzed meconate of silver, and found it composed of

Meconic acid . .	168·8 or 12·73
Oxide of silver . .	192·2 or 14·5
	361.0

He analyzed meconic acid, and obtained

Carbon	41·54 or 7 atoms	= 5·25 or per cent.	42
Hydrogen	2·07 or 2 atoms	= 0·25 — —	2
Oxygen	56·39 or 7 atoms	= 7 — —	56
		12·5	100

* Annalen der Pharmacie, vii. 239.

According to this determination, the atomic weight of meconic acid is 12·5, which approaches pretty nearly to the number obtained by analyzing meconate of silver. Doubtless, the difference is owing to the difficulty of obtaining meconate of silver perfectly anhydrous.

Meconic acid combines with bases in three proportions; it forms with them neutral salts, bisalts, and disalts. The bisalts are difficultly deprived of their bases, they strike a very deep red with the persalts of iron. This colour disappears when the iron is reduced to protoxide, but reappears when the metal is again peroxidized. Meconates of potash and ammonia become less soluble when they contain an excess of acid. The neutral meconates of barytes, strontian, lime, lead, are almost insoluble; but become soluble when they contain an excess of acid.

The meconates are, in general, insoluble in alcohol. When an alcoholic solution of acetate of soda is poured into tincture of opium, meconate of soda precipitates.

When nitrate of silver is poured into a solution of meconic acid, and a little more nitric acid added than is sufficient to dissolve the meconate of silver; if we heat the liquid, the salt is converted into cyanide of silver. The liquid at first limpid, becomes gradually filled with flocks of cyanide. It contains also oxalate of silver in solution. If too much nitric acid be added, much oxalate of silver is formed, but no cyanide. For these curious facts we are indebted to Liebig.

SECT. XV.—OF PYROMECONIC ACID.

This acid was first examined by Robiquet in 1832. It is obtained when meconic or parameconic acid is distilled.

It melts, when heated to 248°, and then has the appearance of an oil. It volatilizes at a gentle heat. It is soluble in water, and still more soluble in alcohol. Muriatic, sulphuric, and nitric acids act upon it as they do on metameconic acid. Like the meconic and metameconic acids it reddens the persalts of iron.

Meconic or metameconic acid, when distilled, gives about one-fifth of its weight of pyromeconic acid. It is purified by pressure between the folds of blotting paper and repeated crystallizations.

Robiquet analyzed the pyromeconate of lead and found it composed of

Pyromeconic acid	.	1302·7 or 13·07
Oxide of lead	.	1395·0 or 14
		2697·7

According to this analysis the atomic weight of pyromeconic acid is about 13.

He analyzed the crystallized pyromeconic acid and anhydrous pyromeconate of lead, and obtained

	From Acid.	From Salt of Lead.
Carbon	52·70	58·7
Hydrogen	3·64	2·9
Oxygen	43·66	38·4
	100·00	100

Now the numbers corresponding with this analysis and with the atomic weight of pyromeconic acid are

10 atoms carbon	= 7·5	or per cent.	58·25
3 atoms hydrogen	= 0·375	— —	2·91
5 atoms oxygen	= 5·0	— —	38·84
	12·875		100

The crystals are C^{10} H^4 O^6, or they are pyromeconic acid combined with an atom of water.*

This constitution of pyromeconic acid enables us to explain its formation from the other two acids.

Metameconic acid .	C^{12} H^4 O^{10}
Subtract 2 carbonic acid	C^2 O^4
1 water . .	H O
Remain . . .	C^{10} H^3 O^5

which is an atom of pyromeconic acid. So that metameconic acid may be resolved into 1 atom pyromeconic acid, 2 atoms carbonic acid, and 1 atom water.

2 atoms meconic acid are .	C^{14} H^4 O^{14}
Subtract 4 atoms carbonic acid	C^4 O^8
1 atom water .	H O
Remain 1 atom pyromeconic	C^{10} H^3 O^5

So that 2 atoms of mecomic acid may be resolved into 1 atom pyromeconic acid, 4 atoms carbonic acid, and 1 atom water.

SECT. XVI.—OF METAMECONIC ACID.

This acid, as has been already observed, was first accurately distinguished from meconic acid by M. Robiquet in 1832.†

The best method of obtaining it is to dissolve meconate of potash or of lime, to add the requisite quantity of muriatic acid to decompose the salt, and then to boil the liquid for some time. The metameconic acid precipitates much less soiled with colouring matter than when we decompose meconic acid by boiling it in water. It is rendered colourless by treating it with animal charcoal.

Like meconic acid it strikes a red with the salts of peroxide of iron. It is less soluble in water than meconic acid. Its crystals are hard and granular, and require about 16 times their weight of water to dissolve them. Muriatic acid does not alter them. Sulphuric acid destroys them by long-continued boiling. Nitric acid

* See Ann. de Chim. et de Phys. li. 251. Ibid. li. 236.

converts them into oxalic acid. When distilled they give pyromeconic acid.

Liebig* analyzed metameconate of silver in order to determine the atomic weight of the acid. It was composed of

Metameconic acid	.	125·71 or 19·96
Oxide of silver	.	91·29 or 14·5
		217·00

He analyzed the acid and obtained

Carbon	45·8 or 12 atoms	= 9	or per cent.	46·15
Hydrogen	2·7 or 4 atoms	= 0·5	— —	2·57
Oxygen	51·5 or 10 atoms	= 10	— —	51·28
	100	19·5		100·00

According to this constitution the atom of metameconic acid is 19·5. From this composition it is easy to see how meconic acid, by the abstraction of carbonic acid, is converted into metameconic acid,

Meconic acid is . .	C^7 H^2 O^7
Subtract 1 atom carbonic acid	C O^2
There will remain	C^6 H^2 O^5

which is just half an atom of metameconic acid.

SECTION XVII.—OF GALLIC ACID.

The history of gallic acid, and the most economical process for obtaining it have been given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 99).

When pure it does not alter the transparency of a solution of isinglass. The crystals are colourless needles, which, according to Braconnot, require 100 times their weight of cold water to dissolve them. When dropt into a solution of persulphate of iron, a deep blue precipitate falls, much more soluble than tannate of peroxide of iron. This precipitate dissolves slowly, and without the assistance of heat in the liquid in which it was formed; and after an interval of some days, this liquid becomes almost colourless. Sulphuric acid takes almost the whole of the iron from gallic acid, and protosulphate of iron crystallizes in the liquid, the iron being reduced to protoxide by the destruction of a portion of the gallic acid. The same changes are produced in a few minutes if we boil the liquor; and in that case carbonic acid gas is disengaged. Tannin exhibits a similar reaction, and in all cases prussiate of potash gives a greenish precipitate, showing the deoxidizement of the persulphate of iron. Gallic acid occasions no precipitate in the salts containing the vegetable alkaloids. With barytes, strontian, and lime water, it forms white precipitates, which redissolve in an excess of acid, and crystallize in prismatic needles, having a satiny lustre, and not altered by exposure to the air. These salts assume various colours, from green to deep red, and are destroyed when exposed to the influence of the air, and an excess of base.

* Annalen der Pharmacie, vii. 420.

Potash, soda, and ammonia, form, with gallic acid, very soluble salts, quite colourless, while kept from the contact of oxygen; but when this gas is present, it is absorbed in great quantity, and the salts assume a deep brown colour.

Acetate or nitrate of lead, poured into a solution of gallic acid, produces a white precipitate, the colour of which is not altered by exposure to the air.*

Gallic acid dissolved in water, and left to itself in an open vessel, undergoes gradual decomposition, a mucilaginous matter is formed, and a black substance, which Dobereiner considers as ulmin.†

When the crystals of gallic acid are exposed to a gentle heat, they give out water and effloresce. A quantity of these crystals, dried at the temperature of 248°, were analyzed by Pelouze and Liebig, by means of oxide of copper. They obtained

	Pelouze.	Liebig.
Carbon	49·51	49·17
Hydrogen	3·67	3·64
Oxygen	46·82	47·19
	100·00‡	100·00§

M. Pelouze made two analyses of gallate of lead, and found the salt composed of

Gallic acid . .	95·3 or 10·7
Protoxide of lead .	124·7 or 14
	220·0

This makes the atomic weight of the acid 10·7. Now

7 atoms carbon	=5·25	or per cent.	49·42
3 atoms hydrogen	=0·375	— —	3·53
5 atoms oxygen	=5	— —	47·05
	10·625		100·00

give an atomic weight which agrees very nearly with that deduced from gallate of lead, and at the same time coincides sufficiently with the mean of the analyses of Pelouze and Liebig.

The crystals of gallic acid are composed of

1 atom gallic acid . .	10·625
1 atom water . . .	1·125
	11·75

Now that we are acquainted with the composition of tannin and gallic acid, it is easy to explain the way in which tannin, by absorbing oxygen is converted into gallic acid, carbonic acid, and water.

For 2 atoms tannin $C^{36}\ H^{18}\ O^{24} + O^{30}$ are equal to

* Pelouze, Ann. de Chim. et de Phys. liv. 348.

† Ann. de Chim. et de Phys. xxiv. 335. ‡ Ibid. liv. 350.

§ Ibid. lvii. 419.

3 atoms gallic acid .	C^{21}	H^{9}	O^{15}
15 atoms carbonic acid .	C^{15}		O^{30}
9 atoms water . .		H^{9}	O^{9}
	C^{36}	H^{18}	O^{54}

Consequently, every two atoms of tannin absorb 24 atoms oxygen, and are decomposed into 3 atoms gallic acid + 15 atoms carbonic acid + 9 atoms water.

SECTION XVIII.—OF PYROGALLIC ACID.

Berzelius stated it as his opinion that gallic acid, obtained from the infusion of nutgalls by the process described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 100), was not free from tannin, and that the only method of procuring gallic acid in a state of purity was to sublime it. This opinion was examined by Braconnot,* who showed that when gallic acid is sublimed, it is converted into a substance possessing quite different properties from the gallic acid of Scheele. He therefore gave it the name of *pyrogallic acid*, and showed that gallic acid obtained by his own process is quite pure. These conclusions have been confirmed by the more recent experiments of Pelouze.†

To prepare pyrogallic acid we must expose gallic acid in a retort to a temperature between 410° and 428°. Pyrogallic acid sublimes. If the temperature be allowed to get as high as 464°, not the least trace of pyrogallic acid will be obtained; but another acid, namely, the *metagallic*. The best way of preparing pyrogallic acid is to fill a retort half full of gallic acid, and to plunge it into an oil-bath. A thermometer ought to be kept constantly in the oil, that we may be sure that the heat does not get beyond the proper point.

Scheele was the first person who obtained pyrogallic acid; but he was not aware of the difference between it and the common gallic acid.‡ Deyeux afterwards repeated Scheele's experiment. He distilled with precaution a quantity of nutgalls. Much carbonic acid, a volatile oil, tar, and an acid liquid came over. This last liquid, when filtered and left to spontaneous evaporation, deposited many crystals of pyrogallic acid.§ But Deyeux did not suspect, any more than Scheele, that the acid thus obtained differed from common gallic acid.

Pyrogallic acid obtained by sublimation is in crystalline plates, which are white and brilliant, and contain no water. The taste is cooling and bitter. The acid reddens litmus paper. At the temperature of 55° it is soluble in 2·25 times its weight of water. It is soluble also in alcohol and ether. When the solution of pyrogallic acid is exposed to the air, it gradually assumes a deep colour, and in a few days is decomposed; being converted into a substance possessing the characters of ulmin. When sulphuric acid is mixed with pyrogallic acid, and slightly heated, no change of colour or decom-

* Ann. de Chim. et de Phys. xlvi. 206.
† Ibid. xxxiv. 348.
‡ Crell's Chemical Journal, i. 29.
§ Jour. de Phys. xlii. 416.

position takes place; but at a higher temperature sulphurous acid is exhaled, and the liquid assumes a brown colour.

Pyrogallic acid melts when heated to 239° and boils at 410°. Its vapour is colourless, and slightly irritating. At the temperature of 482° it becomes black, water is disengaged, and there remains behind a considerable residue of metagallic acid.

Potash, soda, and ammonia, form, with pyrogallic acid, very soluble salts. Pyrogallate of potash crystallizes in rhomboidal tables, which are beautifully white. This acid occasions no precipitate in barytes or strontian water. Nor does it become coloured, unless oxygen be in contact with it.

When persulphate of iron is poured into a solution of pyrogallic acid, whether cold or hot, it is instantly changed into protosulphate, and at the same time the liquid assumes a beautiful reddish-brown colour, without depositing any precipitate. No carbonic acid is formed as is the case when tannin or gallic acid is substituted for pyrogallic acid. If instead of pyrogallic acid we employ a pyrogallate, and mix it with a solution of peroxide of iron, the liquid assumes a deep blue colour, while at the same time a precipitate of the same colour falls. Protosulphate of iron when mixed with pyrogallic acid gives the liquid a blackish-blue colour.

Pyrogallic acid was analyzed by M. Pelouze, and by M. Liebig, and M. Berzelius. They obtained

	Pelouze.	Liebig.	Berzelius.
Carbon	56·74	56·86	56·64
Hydrogen	4·83	4·86	5·00
Oxygen	38·43	38·28	38·26
	100·00*	100·00†	100‡

Berzelius likewise analyzed pyrogallate of lead, and found it composed of

Pyrogallic acid . . .	8·047
Oxide of lead . . .	14
	22·047

showing that its atomic weight is about 8. These results lead to the following atomic constitution of the acid

6 atoms carbon	=4·5	or per cent.	57·15
3 atoms hydrogen	=0·375	— —	4·75
3 atoms oxygen	=3	— —	38·10
	7·875		100·00.

Its atomic weight is 7·875. Now

Gallic acid is . .	$C^7 H^3 O^5$
Pyrogallic acid . .	$C^6 H^3 O^3$
Difference . . .	C O^2

* Ann. de Chim. et de Phys. liv. 360. † Ibid. lvii. 420.
‡ Annals of Philosophy, v. 176.

or an atom of carbonic acid. Heat then decomposes gallic acid into 1 atom of pyrogallic acid, and 1 atom of carbonic acid. This was what M. Pelouze found experimentally to be the case.

SECTION XIX.—OF METAGALLIC ACID.

This acid was discovered and named by M. Pelouze in 1833.* When tannin or gallic acid is exposed to the temperature of 484°, carbonic acid still continues to come over, but instead of the crystals of pyrogallic acid which appear when the temperature is no higher than 428°, water passes over in considerable quantity, and runs down the beak of the retort, and there remains behind a black matter, very brilliant, destitute of taste, and completely insoluble in water. This is the *metagallic acid* of Pelouze.

Potash, soda, ammonia and glucina dissolve it with facility. When an acid is poured into the solution, the metagallic acid precipitates in black flocks, quite unaltered.

Metagallate of potash obtained by boiling an alkaline solution, with an excess of metagallic acid in a gelatinous state, produces no change on vegetable blues. It forms black precipitates with the salts of lead, iron, copper, magnesia, zinc, silver, lime, barytes, and strontian.

Metagallic acid disengages carbonic acid from the carbonates of potash, and soda, but it has no action on the carbonate of barytes, nor even on barytes water, no doubt in consequence of its great insolubility, and of the equally great insolubility of metagallate of barytes.

M. Pelouze analyzed metagallate of silver, and found it composed of

Metagallic acid . .	36 or 12·428
Oxide of silver . .	42 or 14·5
	78

He analyzed metagallic acid united to silver, and in a separate state, and obtained

	Salt of silver.	Acid.
Carbon .	73·8	66·00
Hydrogen .	3·2	3·74
Oxygen .	23·0	30·26
	100·0	100

The analysis of the combined metagallic acid leads to the following atomic quantities

12 atoms carbon	=9	or per cent.	72·73
3 atoms hydrogen	=0·375	— —	3·03
3 atoms oxygen	=3	— —	24·24
	12·375		100·00

* Ann. de Chim. et de Phys. liv. 352.

It is C^{12} H^3 O^8, and the uncombined acid is C^{12} H^3 O^8 + H O, or anhydrous acid united to an atom of water.

It has been already stated, that when pyrogallic acid is exposed to a temperature of 484° water passes over, and metagallic acid remains in the retort, and that nothing else except these two substances appears.

Now 2 atoms pyrogallic acid are	C^{12} H^6 O^6
Metagallic acid is . .	C^{12} H^3 O^3
Remain . .	H^3 O^3

or three atoms of water Thus it appears that when pyrogallic acid is exposed to a temperature of 484° every two atoms of it are resolved into an atom of metagallic acid and three atoms of water.

SECTION XX.—OF KINIC ACID.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 108), I have ascribed the discovery of this acid to Vauquelin. But M. Baup has pointed out M. Hoffman of Leer, as the discoverer.* Hoffman accidentally observed a quantity of kinate of lime crystallized in an extract of cinchona. Upon examining these crystals, he ascertained that they were composed of lime, combined with a vegetable acid, which was neither oxalic, tartaric, nor citric acid, nor any acid at that time known. He concluded, from his experiments, that it was an acid *sui generis*, and he attempted in vain to convert it into oxalic acid, by digesting it in nitric acid.†

The only analysis of kinic acid that had been published when the *Chemistry of Inorganic Bodies* was printed, was that of Henry and Plisson, which was evidently inaccurate. Since that time it has been analyzed by Liebig,‡ and Baup.§

M. Liebig found the anhydrous acid composed of

15 atoms carbon	= 11·25	or per cent.	52·63
9 atoms hydrogen	= 1·125	— —	5·26
9 atoms oxygen	= 9·00	— —	42·11
	21·375		100·00

But it usually retains at least, 1 atom of water. It was hydrous acid which was analyzed by M. Baup. Hence the reason why he represents its constitution by

15 atoms carbon	= 11·25	or per cent.	50·000
10 atoms hydrogen	= 1·25	— —	5·556
10 atoms oxygen	= 10·00	— —	44·444
	22·5		100

Liebig found that crystallized kinate of lime, when dried at 302°, lost 29·58 per cent. of water. One hundred parts of the dried salt, when exposed to a red heat, left a quantity of carbonate of lime,

* Ann. de Chim. et de Phys. li. 57. † Crell's Annalen, 1790, i. 314.
‡ Ann. de Chim. et de Phys. xlvii. 193, and Annalen der Pharmacie, vi. 14.
§ Ibid. li. 58.

equivalent to 13·069 of lime. Consequently the crystallized salt contained 9·18 per cent. of lime. The dried salt still contained 2 atoms of water. Hence the constituents of the salt are

Kinic acid .	55·41 or	1 atom
Lime . .	9·18 or	1·01 atom
Water . .	35·41 or	12·1 atoms
	100	

It is clear from this, that the true constitution of the salt is

1 atom kinic acid	21·375	or	per cent.	55·70
1 atom lime	3·5	—	—	9·12
12 atoms water	13·5	—	—	35·18
	38·375			100·00

It is obvious that two of the atoms of the water are intimately combined with the acid. The other ten atoms are water of crystallization.

M. Baup has also examined and analyzed several of the kinates. It will be worth while to state here the result of his experiments.

1. *Kinate of soda.* This salt is easily obtained, by saturating carbonate of soda with kinic acid, and crystallizing by spontaneous evaporation. Its taste is not bitter. At the temperature of 59° it dissolves in half its weight of water. It is composed of

1 atom kinic acid . . .	22·5
1 atom soda	4
4 atoms water	4·5
	31·0

M. Baup could neither obtain kinate of potash nor of ammonia in a crystallized state.

2. *Kinate of lime.* This salt, which exists in considerable quantity in several species of cinchona, crystallizes in rhomboidal plates with angles of about 78° and 112°, often rendered hexagonal plates by the truncation of the acute angles. They are foliated, and easily split into brilliant folia. It is soluble in six times its weight of water at 61°. Its constituents, as determined by Liebig, are

1 atom hydrous kinic acid	23·625
1 atom lime . . .	3·5
10 atoms water . . .	11·25
	38·375

3. *Kinate of barytes.* It is easily formed, by saturating kinic acid with carbonate of barytes. It crystallizes in dodecahedrons, consisting of two six-sided pyramids, applied base to base. M. Baup never observed it under the form of acute octahedrons, described by Henry and Plisson. This salt effloresces. It is composed of

1 atom hydrous kinic acid .	22·5
1 atom barytes . . .	9·5
6 atoms water . . .	6·75
	38·75

4. *Kinate of strontian.* Its shape is the same as that of kinate of lime. But it is easily distinguished by the rapidity with which it effloresces when exposed to the air; whereas the kinate of lime remains unaltered. At 54° it dissolves in twice its weight of water. It is composed of

1 atom hydrous kinic acid .	22·5
1 atom strontian . . .	6·5
10 atoms water . . .	11·25
	40·25

When it is allowed to effloresce, it loses 3 atoms of its water and retains the other 7.

5. *Kinate of lead.* It crystallizes in needles; but the solution requires to be so concentrated before it crystallizes, that it is difficult to extract the crystals. When dried, pulverized, and exposed to the air in a warm room, it was found composed of

1 atom hydrous kinic acid .	22·5
1 atom oxide of lead . .	14
2 atoms water . . .	2·25
	38·75

6. *Subkinate of lead.* This salt may be obtained by mixing subacetate of lead with kinate of soda, or kinate of ammonia, taking care not to add an excess of subacetate. The precipitated subkinate of lead ought to be washed, and dried as completely as possible, excluded from the action of the air, otherwise it will imbibe carbonic acid. M. Baup did not succeed in determining the water which it contains; but he found the dry salt composed of

Kinic acid . . .	27·273
Oxide of lead . . .	72·727
	100·000

This corresponds with

1 atom kinic acid
4·285 atoms oxide of lead.

Probably it consists of tetartokinate of lead, mixed with a little oxide of lead. We have no evidence that the whole oxide of lead is in combination with the acid. Indeed, so odd a combination as 4·285 atoms oxide of lead with 1 atom kinic acid, is a very improbable thing.

7. *Kinate of copper.* This salt may be obtained, by dissolving carbonate of copper in kinic acid, taking care to leave a small excess of acid. By evaporation we obtain a greenish salt, which should be redissolved in water, containing a little kinic acid. By repeating this process twice, and crystallizing each time, we obtain the salt pure. It crystallizes in foliated needles, has a pale blue colour, and effloresces in the air, losing $\frac{2}{3}$ths of its water of crystallization. When dissolved in water it undergoes spontaneous decomposition, subkinate of copper precipitating. Its constituents are

1 atom kinic acid . .	22·5
1 atom oxide of copper . .	5
5 atoms water . .	5·625
	33·125

8. *Subkinate of copper.* It is obtained by heating a dilute solution of kinic acid in contact with an excess of carbonate or oxide of copper. It forms small brilliant green crystals, not altered by exposure to the air. At the temperature of 64° it dissolves in between 1150 and 1200 times its weight of water. Boiling water dissolves more, and the salt crystallizes on the solution cooling. Its constituents are

Kinic acid . . .	57·931
Oxide of copper . . .	27·586
Water	14·483
	100·000

By the analysis of Liebig,* it is composed of

1 atom kinic acid . .	= 21·375
2 atoms oxide of copper .	= 10
4 atoms water . .	= 4·5
	35·875

9. *Kinate of silver.* When a solution of kinate of silver is evaporated in the dark by a moderate heat, or under the vacuum of the air-pump, it forms a very white anhydrous salt in little sphericles. When heated it melts, swells, gives out abundant vapours, and leaves metallic silver behind. It is composed of

1 atom kinic acid . .	21·375
1 atom oxide of silver . .	14·5
	35·875

10. *Kinate of cinchonina.* This salt, at 59°, dissolves in half its weight of water. It contains 4 atoms of water of crystallization.

It is partially decomposed by alcohol. If we dissolve it in a quantity of hot alcohol not sufficient to keep it in solution after becoming cold, a salt is deposited in brilliant crystals, which are short prisms, with from 4 to 6 faces truncated obliquely. These crystals become slowly opaque. While transparent they are very soluble in water; even air, saturated with moisture, causes them to run into a liquid. A little cinchonina separates when we dissolve them. The aqueous solution of these crystals reacts as an acid, the alcoholic solution as an alkali, on litmus paper.

11. *Kinate of quinina.* This salt, at 52°, dissolves in 3½ times its weight of water, and in 0·88 of its weight of alcohol. It contains 4 atoms of water of crystallization.

* Annalen der Pharmacie, vi. 17.

SECT. XXI.—OF PYROKINIC ACID.

I have nothing to add to the imperfect account of this acid given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 110).

SECT. XXII.—OF ELLAGIC ACID.

Little additional information respecting this acid has been obtained by chemists since the account of it inserted in the *Chemistry of Inorganic Bodies* (vol. ii. p. 104).

Pelouze, after drying it as much as possible, subjected it to an ultimate analysis, by means of oxide of copper, and obtained

Carbon	55·14 or 7 atoms	= 5·25	or per cent.	55·26
Hydrogen	2·71 or 2 atoms	= 0·25	— —	2·63
Oxygen	42·15 or 4 atoms	= 4·00	— —	42·11
	100*	9·5		100·00

If these atomic numbers be adopted the atomic weight of ellagic acid will be 9·5. Now M. Pelouze found that when ellagic acid was dried in a temperature of 248° it lost 11·7 per cent. of its weight, and was then composed of

Pure ellagic acid .	88·3 or 8·49
Water . . .	11·7 or 1·125
	100·0

If we admit the acid to be a compound of 1 atom anhydrous acid and 1 atom water, its atomic weight, according to this experiment, would be 8·5. Now this does not differ more from 9·5, the number deduced from its atomic constitution, than might be expected in an experiment of this nature. From this atomic constitution it is easy to see the relation between ellagic and gallic acid.

Gallic acid is . . .	$C^7 H^3 O^5$
Ellagic acid . . .	$C^7 H^2 O^4$
Difference . . .	H O

So that an atom of ellagic acid + 1 atom of water constitutes an atom of gallic acid.

M. Robiquet mixed 1 part of crystals of gallic acid with 5 parts of concentrated sulphuric acid, in a retort, and applied heat very gradually. The gallic acid was dissolved, and the liquid became transparent. The heat being cautiously increased, the liquid became first fawn-coloured, then rose-red, and passed through all the shades of red to crimson, and, at the same time, became viscid. When heated to 284°, traces of sulphurous acid began to appear. The process was stopped, the liquid allowed to cool, and then mixed by little and little with cold water. An abundant reddish-brown precipitate fell partly in flocks and partly in small crystals. These crystals were a beautiful reddish-brown like kermes, and exceeded one-half, or approached to two-thirds, of the gallic acid employed. When heated to 248° they lost $10\frac{1}{2}$ per cent. of their weight, and

* Ann. de Chim. et de Phys. liv. 357.

their colour was injured. When heated over the fire they are decomposed slowly, but are at last charred and covered with little red crystals. When analyzed, they were found composed of C^7 H^2 O^4, and of course had the same composition as *ellagic* acid. Like that acid they are insoluble in water; but their behaviour with the alkalies is different. An excess of potash holds ellagic acid in solution, but in proportion as the excess of potash combines with carbonic acid, small scales of ellagate of potash, little soluble in water, are deposited. The red crystals neutralize potash; but no scales fall. After a long interval small crystals appear, having a red colour, and being very soluble in water. Robiquet found that this red-coloured acid possessed powerful dyeing properties, cloth impregnated with iron when treated with them become violet, brown, or black, according to the quantity of peroxide of iron present. With alum mordant they gave the same red colours as madder. Robiquet conceives that this red substance exists in nutgalls, and is disposed to ascribe to it the use of galls in the process of dyeing Turkey red. But this opinion is not likely to be correct.*

SECT. XXIII.—OF CAHINCIC ACID.

This acid was discovered, in 1830, in the bark of the root of the *Kahinça (chiococca racemosa anguifuga, flore luteo)* a plant which grows in Brazil, in the province of Minas Geraes, and belongs to the order of *rubiaceæ*. It is a shrub which rises to the height of six feet, or even higher. The bark has a brown colour, an aromatic but disagreeable smell, and an intensely bitter taste. It is hard, brittle and compact, and is easily separated by striking the root between two hard bodies. By the inhabitants of Brazil it has long been employed as a cure for intermittent fevers. But it was first made known in Europe as a valuable medicine by Major Langsdorf. MM. François, Caventou, and Pelletier, received a cargo of it from Brazil, and subjected it to a chemical analysis. The most important of the constituents discovered in this bark was *cahincic* acid.†

This acid may be extracted from the Kahinça bark by the following process:—Digest the bark in alcohol, evaporate the alcoholic solution to dryness, and dissolve the residue in water. Add lime to the solution till the liquid loses all taste of bitterness. A calcareous salt is deposited which is cahincate of lime. Decompose this salt by oxalic acid and the cahincic acid is disengaged. It may be purified by repeated solutions and crystallizations.

It may be precipitated directly from the aqueous decoction of the bark by dropping into it muriatic acid. The acid is deposited slowly, during several days, in the state of small crystals. But when got in this way it is always deeply coloured, and a good deal remains in solution, being kept from precipitating by the colouring matter.

Cahincic acid requires six hundred times its weight of water and

* Jour. de Pharmacie, xxii. 484.

† Ann. de Chim. et de Phys. xliv. 291, and Jour. de Pharmacie, xvi. 265.

nearly as much ether to dissolve it. But it is very soluble in alcohol, and when dissolved in hot alcohol it crystallizes as the liquid cools. The crystals are small white needles usually in the form of stars. The acid has no smell. When put into the mouth it appears at first tasteless, but soon gives an impression of intense bitterness. At 212° it loses only a little water of crystallization; but when strongly heated in a glass tube it becomes soft, is charred, and gives out white vapours, which are deposited in small light crystals on the sides of the glass. These crystals have no bitter taste and contain no ammonia.

Sulphuric acid dissolves cahincic acid and chars it immediately. Muriatic acid dissolves it, but almost immediately assumes the form of a jelly, which is changed by the addition of water into white translucent flocks quite destitute of bitterness. Nitric acid acts in the same way, and by a long-continued action it produces a yellow bitter matter without any trace of oxalic acid. Dilute muriatic or nitric acid scarcely dissolves cahincic acid. Concentrated acetic acid dissolves it, and, when assisted by heat, converts it into an insipid gelatinous mass.

With potash, ammonia, barytes and lime it forms neutral salts, soluble in water and alcohol. The strong acids precipitate cahincic acid from those solutions. None of them can be made to crystallize. When lime water is poured into an aqueous solution of neutral cahincate of lime, a copious precipitate of dicahincate of lime falls, which is soluble in boiling alcohol, from which it is deposited in large white flocks, which are strongly alkaline.

M. Liebig subjected a portion of this acid to analysis. He found that 100 parts of it, when heated to 212°, lost 9 parts of water. Now, if the crystals, as is usual with these acids, contained 1 atom of water, we have their composition,

Cahincic acid . .	91 or 11·375
Water . . .	9 or 1·125
	100

This would make the atomic weight 11·375.

The dried crystals analyzed by oxide of copper gave

Carbon	56·74 or $7\frac{1}{2}$ atoms	= 5·625	or per cent.	57·06
Hydrogen	7·50 or 6 atoms	= 0·75	— —	7·50
Oxygen	35·76 or $3\frac{1}{2}$ atoms	= 3·5	— —	35·44
	100*	9·875		100·00

These numbers almost coincide with the result of Liebig's analysis; but the atomic weight resulting is too small. The following atomic constitution would give the atomic weight of the acid:—

$8\frac{1}{2}$ atoms carbon	= 6·375	or per cent.	56·05
8 atoms hydrogen	= 1	— —	8·79
4 atoms oxygen	= 4	— —	35·16
	11·375		100·00

* Ann. de Chim et de Phys. xlvii. 185.

But it does not come sufficiently near Liebig's analysis to give us full confidence in its accuracy.

It is clear that a much greater number of experiments and analyses upon a larger quantity of the acid than Liebig possessed would be requisite before the nature and properties of this curious acid can be accurately understood.

SECT. XXIV.—OF BICOLORIN, OR BICOLORIC ACID.

It was observed a good many years ago, by Löseke, that various vegetables, when digested in hot water, give a solution which appears *yellow* by transmitted light, but *violet* or *blue* by reflected light. The wood of the *Guilandina Moringa* or *lignum nephritum* was first used for this purpose. Löseke remarked, that the colour of the infusion of the *guilandina wood* is destroyed by acids, but restored again by alkalies. In 1785, Remmier remarked that the bark of the horse chestnut gave an infusion possessing similar properties. Sometime afterwards, Raab gave the substance which produces this change of colour, the name of *schillerstoff*, and mentioned several of its properties. This German name was by Martius of Erlangen translated into *bicolorin*, and by Kastner into *polychrome*. Some attempts were made both by Raab and Martius to determine the properties of bicolorin, but they were not very successful.

Minor gave a process which he considered as capable of furnishing pure bicolorin from the bark of the horse chestnut.* In 1835 Trommsdorf published a set of experiments on the preparation of bicolorin, described its properties, and H. Trommsdorf analyzed it and determined its constitution. His process was as follows.†

Ten pounds of the bark of the horse chestnut reduced to powder, were mixed with six times their bulk of alcohol, of the specific gravity 0·8631, and digested at first in a gentle heat, but at last the liquid was made to boil. The alcohol was then drawn off while hot, and the bark digested a second time with half the quantity of alcohol used at first. This last portion was then separated from the bark by expression—the tincture was filtered and distilled till seven eighths of the whole liquid had passed over. The residue was left exposed for some weeks in an open vessel. The impure bicolorin precipitated. It was washed with ice-cold water, to separate it as far as possible from the impure matter with which it was mixed. It was then dissolved in a boiling heat, in a mixture of ether and alcohol. It was deposited from this solution as the liquid cooled. These solutions and precipitations were repeated till the bicolorin assumed a snow-white colour. It was then considered as pure.

Bicolorin has a snow-white colour, and is usually in the state of a light flocky powder, somewhat resembling carbonate of magnesia in appearance. It is not capable of crystallizing. Its taste is

* For this historical sketch, I am indebted to Trommsdorf. See Ann. der Pharmacie, xiv. 189.

† Ann. der Pharmacie, xiv. 193.

bitterish, and it has no smell. It dissolves in 12·66 times its weight of boiling water. The solution on cooling, concretes into a bulky white mass. When this white matter is dried at 212° it loses only from 0·5 to 0·75 of its weight.

Water of the temperature of 51° dissolves only $\frac{1}{672}$ part of its weight of bicolorin. At the temperature of 77°, water dissolves $\frac{1}{376}$th of its weight of it. The aqueous solution is almost colourless, but gives a feeble blue shade. It variegates stronger when mixed with well water, and reflects a magnificent sky blue. One part of bicolorin gives this variegating property to $1\frac{1}{2}$ millions of its weight of water.

It is soluble in 24 times its weight of boiling alcohol, of the specific gravity 0·798. But the greater part precipitates in flocks when the solution cools. Absolute ether dissolves a scarcely perceptible portion of bicolorin. It requires seventeen times its weight of a boiling mixture, of 1 part ether and 5 parts alcohol, to dissolve it. When a drop of this solution is let fall on water, it variegates strongly.

The aqueous solution loses its variegating quality when mixed with a few drops of sulphuric, nitric, muriatic, phosphoric, or arsenic acids. The same effect is produced by boracic, tartaric, malic, and even acetic acids. A few drops of ammonia, potash, soda, lime, or barytes solutions restore the variegating property, immediately.

All alkaline bodies increase the variegating property; but give a yellow colour to the solution. No precipitate is produced by the alkalies, lime, barytes, or strontian, or their carbonates. All these bodies increase the solubility of bicolorin in water. Acids on the contrary throw it down.

Chlorine water instantly gives a red colour to the aqueous solution of bicolorin. The colour changes to brown and then to yellow, and the variegating property is destroyed. But alkalies again restore the variegating property.

Bicolorin reddens litmus paper, and possesses the characters of a weak acid. When heated it melts into a dark brown liquid, giving out a thick white vapour, like that of burning sugar, and burns with a light coloured flame, leaving a bulky charcoal which may be burnt all away without leaving any residue. In a distilling heat it undergoes decomposition.

Bicolorin was analyzed by M. Herrmann Trommsdorf, who obtained*

Carbon	51·70 or 8	atoms =	6	or per cent	51·90
Hydrogen	4·97 or $4\frac{1}{2}$	atoms =	0·5625	— —	4·86
Oxygen	43·33 or 5	atoms =	5	— —	43·24
			11·5625		100·00

* Ann. der Pharmacie, xiv. 205.

SECTION XXV.—OF CAFFEIC ACID.

Coffee is the fruit of the *coffea Arabica*, a low evergreen tree, a native of Arabia. It was unknown to the ancient Greeks and Romans. The generally received opinion is, that the use of its infusion as a drink originated in Ethiopia. But the practice of drinking it in Arabia was introduced from Persia by the Mufti of Aden, in the 15th century. In 1554, its use first began at Constantinople, from whence it was gradually adopted in the western parts of Europe. At Marseilles it was begun in 1644. At Paris it was nearly unknown till the arrival of the Turkish ambassador, Soliman Aga, in 1669. In 1672 the first coffee-house was established in Paris by an Armenian named Pascal; but meeting with little encouragement he went to London, where the beverage had been previously introduced in the year 1652, when Mr Edwards, a Turkey merchant, brought from that country a Greek servant, of the name of Pasqua, who understood the method of preparing coffee, and first sold it in London, in a house which he kept for that purpose in George Yard, Lombard Street.*

The first attempt at a chemical examination of coffee was by Neumann, or more probably by Dr Lewis in 1759.† It was found that coffee by roasting lost one-fourth of its weight. $\frac{5}{16}$ths of the coffee were dissolved in water, and spirits dissolved a little more. The effect of distilling the decoction and tincture of coffee was tried. But the chemistry of vegetable bodies had at that time made so little progress, that it would be useless to give the results.

In the year 1800, Herrmann, an apothecary at Magdeburg, made a comparative set of experiments on Levant and Martinique coffee.‡ He treated the coffee with alcohol and with water, remarked the different quantities of each coffee dissolved by these liquids, and made some experiments on the matters extracted by them. But his experiments did not elicit any new facts of much importance.

In 1802, Mr Chenevix made some experiments on coffee.§ He digested unburnt coffee in water, filtered the liquid, and precipitated by means of chloride of tin. The precipitate was washed, diffused in water, and the tin separated by sulphuretted hydrogen. The filtered liquor being evaporated to dryness, left a yellow semitransparent matter, soluble in water and alcohol, and striking a green with salts of iron. The taste was bitter, and he considered it as the bitter principle of coffee.

In 1806, an elaborate memoir on coffee was published by Cadet,‖ in which he endeavoured to determine the constituents of coffee by analysis, and to ascertain the changes induced by roasting. In the same year a valuable set of experiments on coffee by M. Payssé was published by M. Parmentier.¶ He showed among other im-

* Woodville's Medical Botany, i. 183; and Houghton, Phil. Trans. xxi. 311.
† Lewis's Neumann's Chemistry, p. 378.
‡ Crell's Annalen, 1800, ii. 108 and 176.
§ Phil. Mag. xii. 350.
‖ Ann. de Chim. lviii. 216.
¶ Ibid. lix. 196.

portant facts that the peculiar principle discovered by Chenevix in coffee was an acid to which he gave the name of *caffeic acid*, and the properties of which he describes.

In 1808, a new and elaborate analysis of coffee was published by Schrader.* But though his experiments were useful in clearing the way, he did not succeed in obtaining any of the peculiar principles of coffee in a separate state. In 1821, Robiquet discovered a crystallizable substance in coffee, to which the name of *caffein* has been given, but which does not possess alkaline properties.† The properties of caffein were farther investigated by Pelletier.‡ In 1821, Runge and Garot§ pointed out an easy method of obtaining caffein, and showed also that coffee contained a peculiar acid, thus confirming the statement of Payssé.‖ These statements were confirmed, and the properties of caffeic acid described at some length by Pfaff.¶

To obtain caffeic acid, the precipitate by means of acetate of lead from the infusion of coffee is mixed with water, and the lead precipitated by sulphuretted hydrogen. The filtered liquid is evaporated to the consistence of a syrup, and then mixed with its own bulk of alcohol. The portion held in solution by the alcohol is *tanno-caffeic acid*, the portion thrown down *caffeic acid*.

Caffeic acid is a white powder insoluble in alcohol, but soluble in water. The aqueous solution has a slight colour. It reddens litmus paper. It is either not at all or only very slightly opalized by caustic ammonia, carbonate of potash, or soda, lime water, nitrated suboxide or oxide of mercury, or by acetate or diacetate of lead. But the first three of these substances give it a brown colour, while lime water colours it yellow. When mixed with perchloride of iron it does not become green, and with ammoniated copper it does not strike the green, which is so characteristic of malic acid. With barytes water it throws down a yellow precipitate, soluble in nitric acid, and with albumen a flocky precipitate, without any shade of green. The characteristic property of caffeic acid is this :—when strongly heated it emits a smell precisely similar to that of roasted coffee. According to the analysis of Professor Pfaff, its constituents are

Carbon	29·1 or 12 atoms	= 9	or per cent.	29·88
Hydrogen	6·9 or 17 atoms	= 2·125	— —	7·06
Oxygen	64·0 or 19 atoms	=19	— —	63·06
		30·125		100·00

But no confidence can be put in this formula. Indeed, it is obvious from the description, that Pfaff's caffeic acid could not have been pure.

Tanno-caffeic acid. It is obtained by evaporating the alcoholic solu-

* N. Gehlin's Journal, vi. 544.

† Jour. de Pharmacie, xii. 229 ; and Ann. de Chim. et de Phys. xxiv. 183.

‡ Ibid. xii. 229. § Ibid. p. 234. ‖ Materialien zur Phytologie, p. 146.

¶ Sweigger's Jour. lxi. 487, and lxii. 31 ; or Poggendorf's Annalen, xxiv. 376.

tion from which the caffeic acid was precipitated. It is a dark brown extractive substance, having a very acid and astringent taste, without the least flavour of bitterness or sweetness. In water it dissolves in all proportions, but is less soluble in absolute alcohol. The aqueous solution diluted till it has become colourless, assumes a fine emerald-green colour when mixed with nitrated peroxide of iron. When the solution is concentrated a dark-green precipitate falls. By persulphate of iron it is not at first altered; but after some time it assumes a green colour, and at last a white precipitate falls. With ammonieted copper, it assumes first a pure pistacio-green colour, then a dark-green precipitate falls. When mixed with chloride of gold it is green by transmitted, and brown by reflected light, and at last a precipitate of metallic gold falls. With nitrate or subnitrate of mercury it throws down a precipitate, at first grey, but afterwards becoming flesh-red: with lime water an orange-yellow, and with barytes water a sulphur-yellow precipitate. By corrosive sublimate, tartar emetic, and isinglass solution, it is not altered. By ammonia, potash, and soda, it is coloured reddish-brown; by carbonate of potash or soda, at first greenish, then reddish-brown which becomes a full green when exposed to the air. Albumen, by this acid, is thrown down in flocks, and the liquid, after a certain time, becomes grass-green.

Sulphuric ether dissolves the greatest part of it, and the undissolved portion possesses all the above described characters, except the green colour of the albumen, which it does not produce.

SECTION XXVI.—OF PICROTOXIN OR PICROTOXIC ACID.

This is the substance to which the *cocculus indicus*, the fruit of the *menispermum cocculus* owes its deleterious qualities. Its nature and properties were investigated by Boullay in 1811.* He bestowed upon it the name of picrotoxin, from its bitter taste and its poisonous nature.†

It may be obtained by the following process: Boil the berries in a sufficient quantity of water. Filter the decoction, and add to it acetate of lead as long as any precipitate falls. Filter the liquid a second time, and evaporate it with caution to the consistence of an extract. Dissolve this extract in alcohol of the specific gravity 0·817. Evaporate this liquid to dryness. These alternate solutions and evaporations in water and alcohol must be repeated till the dry residue is completely soluble both in water and alcohol. It is now picrotoxin united with a yellow colouring matter. Agitate it with a small quantity of water. That liquid dissolves the colouring matter, which is very soluble, and occasions the separation of a great number of small crystals which constitute picrotoxin nearly pure. Wash them with a little water and then with alcohol. Picrotoxin thus prepared possesses the following properties:—

It assumes different forms. Most commonly it crystallizes in needles; but some times it is in silky flexible filaments, in tran-

* Ann. de Chim. lxxx. 209. † From πικρος, *bitter*, and τοξικον, *poison*.

sparent plates, in radiating and mammiform masses, or in hard granular crystals.

To dissolve it, 25 times its weight of boiling water, and 150 times its weight of water, at the temperature of 57°, are requisite. Its taste is intensely bitter, and it does not alter the colour of litmus paper.

No reagent is capable of precipitating it from its aqueous solution. Alcohol of the specific gravity 0·810 dissolves one-third of its weight of it. Sulphuric ether of the specific gravity 0·7 dissolves two-fifths of its weight of it. It is insoluble in oils.

M. Boullay, the discoverer of picrotoxin, considered it as a vegetable alkali, and several of the salts which it forms with acids, have been described. M. Casaseca* has endeavoured to prove, that it is incapable of neutralizing acids. But this alone is not sufficient to deprive it of its alkaline characters.

Pelletier and Couerbe, in their new analysis of the seeds of the *menispermum cocculus*,† turned their particular attention towards the question, whether picrotoxin was entitled to rank as an alkali. They decided in the negative, and consider it as approaching more nearly to the characters of an acid than a base. But when they attempted to unite it with the organic salifiable bases, they were unable to obtain stable and definite compounds.

They found that picrotoxin was incapable of depriving muriatic acid of the property which it has of reddening litmus paper, or even of diminishing that property. Muriatic acid dissolves picrotoxin, and the solution yields beautiful crystals. But when these crystals are washed with a sufficient quantity of water, the whole acid is washed off, and the picrotoxin is obtained pure and unaltered. Similar experiments were made with other acids, with the same results. When picrotoxin is dissolved in acetic acid, we also obtain crystals from the solution. But the whole acetic acid is washed off by cold water, and the picrotoxin is left pure and unaltered.

When picrotoxin and iodine are boiled in distilled water, the liquid becomes and remains acid, in spite of the presence of a great excess of picrotoxin. By repeated crystallizations we obtain the picrotoxin perfectly pure from this solution, without any trace of iodine or hydriodic acid.

The concentrated acids destroy picrotoxin. Sulphuric acid, at the temperature of 57°, does not seem to act at first. But gradually the picrotoxin becomes light yellow, and finally, saffron yellow. The slightest augmentation of temperature causes the destruction of the picrotoxin, which is charred. Nitric and hyponitrous acid transform picrotoxin to oxalic acid.

From these and other similar facts, MM. Pelletier and Couerbe conclude, that picrotoxin has not the property of combining with acids. They do not even facilitate its solution in water.

* Jour. de Pharmacie, xii. 99. † Ann. de Chim. et de Phys. liv. 181.

All the alkaline bodies, on the other hand, facilitate the solution of picrotoxin in water. With potash and soda we may dissolve a considerable quantity of it in water. If we add an acid to the solution, the picrotoxin separates unaltered. We can, by washing, separate the alkaline liquid, and obtain the picrotoxin in a state of purity. But when we heat concentrated solutions of potash, soda, or ammonia containing picrotoxin, that substance undergoes a complete alteration, and is converted into an orange-yellow substance, soluble in the alkali. It may be thrown down by acids in the state of a brown powder. This substance possesses acid characters. But has not been much examined.

Lime, strontian, barytes, and magnesia, unite to picrotoxin, and hinder it from crystallizing in prismatic needles. The crystallizations of picrotoxin from the seeds of the *menispermum* in plates or grains, is owing to the presence of lime.

When an alkaline solution of picrotoxin is subjected to the action of the galvanic battery, the compound undergoes decomposition, and the picrotoxin attaches itself to the positive pole, while the potash goes to the negative pole of the battery. The same result was obtained with solutions of picrotoxin in soda and ammonia.

Pelletier and Couerbe attempted to combine picrotoxin with brucina. They boiled a mixture of 1 part of brucina, and 4 parts of picrotoxin in distilled water. The liquor was filtered while boiling hot. On cooling, it deposited a mass of flexible, dirty-white, silky crystals. They were subjected to pressure and redissolved in boiling water. When the solution cooled, they appeared again with all their original characters. When they were dissolved in water and potash, or soda added, the brucina was precipitated, being recognised by the property which it has of striking a red with nitric acid. When subjected to the action of a galvanic battery, the picrotoxin crystallized round the positive pole, while the brucina crystallized round the negative pole.

They succeeded equally in forming and in decomposing by the galvanic battery, precisely with the same phenomena, picrotoxates of strychnina, quinina, and cinchonina. They found that picrotoxin was rendered less soluble by morphina than by any other of the vegetable alkalies. This seems to show, that the alkalinity of morphina is very feeble. But it acquires a greater degree of solubility than when *per se*, as the solution is precipitated by ammonia, and decomposed by the galvanic battery with the usual phenomena. Narcotina is the weakest of all the alkalies, yet it acquires an increase of solubility by the action of picrotoxin, which appears to combine with it. The picorotoxate of narcotina is precipitated by ammonia, and decomposed by the galvanic battery.

MM. Pelletier and Couerbe, determined the atomic weight of picrotoxin, by analyzing the picrotoxate of lead. They made two analyses. In the first, they found the salt composed of

Picrotoxin . . .	52 or 15·16
Oxide of lead . .	or 14

In the second, of

Picrotoxin . . .	55 or 17·11
Oxide of lead . .	45 or 14

By the first of these analyses, the atomic weight is 15·16, by the second, 17·14.

They analyzed picrotoxin by means of oxide of copper, and the same analysis was made by Oppermann. They obtained

	Pelletier and Couerbe.	Oppermann.
Carbon	60·91	60·09
Hydrogen	6·00	6·11
Oxygen	33·09	33·89
	100·00	100*

These numbers lead to the following atomic constitution :—

12 atoms carbon	= 9	or per cent.	60·51
7 atoms hydrogen	= 0·875	— —	5·88
5 atoms oxygen	= 5	— —	33·61
	14·875		100·00

But this analysis is not satisfactory, because Pelletier and Couerbe have not given the data from which their atomic quantities were deduced.

SECTION XXVII.—OF MECHLOIC ACID.

This acid was discovered by M. Couerbe, and was shortly described by him in a paper, read before the Academy of Sciences of Paris, in July, 1835.†

If a current of chlorine be made to pass over meconin in fusion, it is absorbed, and the meconin becomes first red and then deep yellow. Two new substances are formed; the one white and crystallizable, is *mechloic acid;* the other has a resinous aspect, contains a great deal of chlorine, and may be separated by boiling the product with carbonate of soda.

To purify the mechloic acid, it must be dissolved in potash, and precipitated by nitric acid. It is then white, and crystallized in beautiful prismatic needles, soluble in boiling water, but very sparingly in cold water. It is little soluble in alcohol and ether. Its taste is acrid and acid. It melts when heated to 257°, and is volatilized at a temperature between 374° and 378°. When thrown upon red hot coals, it gives out a white smoke without flame, accompanied by an odour analogous to that of jessamine.

It is, when in the state of chloride, composed, according to Couerbe, of

Chlorine . . .	5·43 or 4·5
Organic matter .	94·57 or 78·37
	100·00

When dissolved in alcohol and digested with oxide of silver, the

* Ann. der Pharm. x. 205. † Ann. de Chim. et de Phys. lix. 148.

chlorine is separated. If we filter and evaporate the solution, we obtain a white, pearly substance in scales, which dissolves in ether, and crystallizes in very short four-sided square prisms. It melts at 320°, and is volatilized at 329°.

It reddens litmus paper, and precipitates the soluble salts of lead and copper; but not those of silver, iron, lime, and mercury.

Sulphuric and muriatic acid do not alter it; nitric acid destroys it, but without changing it into oxalic acid.

It is soluble in boiling alcohol, and ether and water, and crystallizes when the solutions cool.*

Couerbe subjected mechloic acid to analysis, 100 parts yielded 178·66 of carbonic acid, and 36·66 of water. Hence (as it contains no azote), the constituents must be

Carbon	48·727 or 14 atoms	= 10·5	or per cent.	49·12
Hydrogen	4·073 or 7 atoms	= 0·875	— —	4·09
Oxygen	47·200 or 10 atoms	= 10·000	— —	47·79
	100†	21·375		100·00

If the chloride of mechloic acid, the analysis of which is given in last page, be a neutral compound, mechloic acid has an atomic weight of 78·37. To obtain this weight, it would be necessary to multiply the preceding numbers by $3\frac{2}{3}$. This would give us

$51\frac{1}{3}$ atoms carbon . .	= 38·5
$25\frac{2}{3}$ atoms hydrogen . .	= 3·2
$36\frac{2}{3}$ atoms oxygen . .	= 36·6
	78·3

or probably (to get rid of fractions) of

51 atoms carbon . .	= 38·25
26 atoms hydrogen . .	= 3·25
37 atoms oxygen . .	= 37·00
	78·5

making the atomic weight 78·5.

SECTION XXVIII.—OF AMYGDALIC ACID.

This acid was discovered by M. Winckler some years ago, and noticed by him in a paper which he published on the oil of bitter almonds.‡ In the year 1836 he published, in the same journal, a detailed description of the mode of preparing this acid, and an account of its properties.§

His mode of preparing it is the following:—80 ounces of bitter almonds, freed by pressure as much as possible from the fixed oil which they contain, were mixed with 90 lbs. of water, and put into a distilling apparatus and 160 ounces of the water distilled off. This portion was put into a smaller still and 80 ounces of it distilled

* Ann. de Chim. et de Phys. l. 351. † Ibid. lix. 149.
‡ Liebig's Annalen der Pharmacie, iv. 242. § Ibid. xviii. 310.

off. This portion was well agitated in order to mix the volatile oil that had come over with the water, and then 4 ounces of pure muriatic acid, of the specific gravity 1·12 were added, and this mixture was evaporated to dryness in a porcelain dish over the water-bath, taking care to dissipate the whole of the muriatic acid. By this process 330 grains of a yellowish-white imperfectly crystallized matter was obtained. When digested in ether it all dissolved except 90 grains of sal ammoniac. The ether being left to spontaneous crystallization a light yellowish crystalline matter was obtained, having a very sour taste, and reddening litmus paper. Being dissolved in water, and treated with animal charcoal and again crystallized, it was obtained quite colourless, and, in this state, was considered as pure *amygdalic acid*. It appears from this mode of preparation that by the addition of muriatic acid to the oil of bitter almonds and subsequent evaporation, almost the whole of this oil is converted into amygdalic acid and ammonia.

Wöhler and Liebig have since found that amygdalic acid is easily obtained from *amygdalin*. If we dissolve amygdalin in cold barytes water no decomposition takes place. But if the solution is raised to the boiling temperature (though air be excluded) ammonia is disengaged. When air is admitted carbonic acid is disengaged, and a little barytes precipitated. If we boil the solution for a quarter of an hour the decomposition is completed, and all indications of ammonia disappear. A current of carbonic acid passed through the hot liquid throws down the uncombined barytes, and leaves a solution of pure amygdalate of barytes.*

Amygdalic acid thus obtained, has a slight tendency to crystallize, and the crystals constitute usually transparent plates or scales. Its taste is acid, styptic and peculiar. Its smell is faint, but has some resemblance to that of sweet almonds. When heated in a platinum spoon, it gives out water and speedily melts into a yellowish-white liquid, having the consistence of oil, and which, on cooling, concretes into a translucent gummy-looking mass. When the heat is increased the acid flies off in a white smoke, having a smell resembling hawthorn blossom, while a bulky coal remains behind. When this smoke is brought in contact with flame, it catches fire and burns with a red flame.

Amygdalic acid is obtained easily by precipitating the barytes from the amygdalate of barytes by sulphuric acid. It is a slightly acid liquid, which, over the water-bath, dries into a gummy mass. When the solution is left for some time in a warm place, we observe marks of crystallization. It is very deliquescent. It is insoluble in absolute alcohol and in ether, and but little soluble in spirit of wine.

When boiled with binoxide of manganese it undergoes no change; but if we add sulphuric acid we obtain formic acid, carbonic acid, and oil of bitter almonds.

* Ann. de Chim. et de Phys. lxiv. 195.

When heated in a retort it allows the temperature to be raised pretty high before it begins to be decomposed, it becomes brown by degrees, and, when the heat is raised it distils over in a dark reddish-brown, resinous-looking matter, which is very slightly soluble in water, but readily soluble in alkaline ley and in alcohol.

Neither sulphuric nor nitric acid occasion any alteration in the colour of amygdalic acid at the ordinary temperature of the atmosphere.

Wöhler and Liebig analyzed amygdalate of barytes, which they obtained by boiling a solution of amygdalin in barytes water. They could not crystallize this salt. But obtained it in a gummy mass, which may be heated to 374° without decomposition. It becomes white, has the aspect of porcelain, and is easily reduced to powder. 100 parts of the anhydrous salt were composed of

Amygdalic acid . .	85·9 or 57·87
Barytes . . .	14·1 or 9·5
	100·0

Making the atomic weight of the acid 57·87.

The salt being analyzed by oxide of copper gave

Carbon	44·38 or 40 atoms =	30	or per cent.	44·94
Hydrogen	5·28 or 26 atoms =	3·25	— —	4·86
Oxygen	36·24 or 24 atoms =	24	— —	35·99
Barytes	14·10 or 1 atom =	9·5	— —	14·21
		66·75		100·00

It is obvious that amygdalic acid is C^{40} H^{26} O^{24}; that is to say, it is amygdalin combined with two additional atoms of oxygen and deprived of an atom of azote. Hence its atomic weight must be 57·25 or rather more than 1 per cent. lighter than the number resulting from the analysis of amygdalate of barytes.

It forms neutral salts with the bases and disengages carbonic acid from the alkaline and earthy carbonates. The amygdalates, in general, crystallize readily, though some, as amygdalates of potash and ammonia, show no tendency to assume a crystalline form.

1. *Amygdalate of potash.* It may be obtained by digesting solutions of amygdalic acid and carbonate of potash. To obtain the salt in a neutral state the best way is to evaporate to dryness and digest the dry mass in alcohol. That liquid dissolves the neutral portion, while the excess of carbonate of potash remains behind. On evaporating the alcoholic solution, the amygdalate of potash remains behind similar in appearance to soap.

It dissolves readily both in water and alcohol. The solution is neutral, its taste is mild and scarcely saline. When heated, it behaves very similar to amygdalic acid.

2. *Amygdalate of ammonia.* This salt may be obtained by mixing a solution of amygdalic acid with a slight excess of ammonia, and evaporating till that excess is driven off.

The salt is a yellowish-white soft mass, having a mild taste, and

behaving, when heated, like amygdalic acid It is soluble in water and in alcohol.

3. *Amygdalate of barytes.* Obtained by digesting a solution of amygdalic acid over carbonate of barytes. It crystallizes readily, when the solution is evaporated in short, fine prisms. It is much less soluble in water than amygdalates of potash or ammonia. It behaves, when heated, as amygdalate of potash does.

20 parts of amygdalic acid, dried at 86°, decomposed 13·38 parts of carbonate of barytes. A small portion of carbonate of barytes which passes into the solution, precipitates when the liquid is heated.

4. *Amygdalate of silver.* This salt is easily obtained by mixing together solutions of amygdalate of ammonia and nitrate of silver. It falls down in the state of a heavy, white crystalline powder, which is very easily washed. It must be dried in a gentle heat, and where it is excluded from the action of the light. When boiled in water, and the solution filtered while hot, it is deposited on cooling in pretty large crystals, very similar to those of benzoic acid, only having a slight yellow colour.

When heated it melts into a dark-coloured mass, and when the temperature is raised it undergoes decomposition, behaving in the way that amygdalic acid does under the same circumstances, and leaving pure metallic silver behind.

This salt, according to the analysis of M. Winckler, is composed of

Amygdalic acid	54·63 or 52·38	or 1 atom
Oxide of silver	45·37 or 14·5 × 3	or 3 atoms
	100·00	

M. Liebig analyzed amygdalate of copper, and found it composed of

Amygdalic acid .	53·625	or 1 atom
Oxide of copper .	5 × 3	or 3 atoms
	22·875	

When a solution of amygdalic acid is heated with binoxide of manganese, carbonic acid is given off, and oil of bitter almonds distils over, which by the action of the air is converted into benzoic acid. When amygdalic acid is boiled with fuming nitric acid, the formic acid is entirely decomposed, and if we continue the heat till no more acid fumes are observed, and then add water, colourless crystals of benzoic acid are deposited.

SECTION XXIX.—OF TANNIN, OR TANNIC ACID.

Nutgalls are excrescences that grow upon certain species of oak, particularly the *quercus infectoria* and the *quercus cerris.* They are produced by the puncture of the female of the *Cynips gallæ tinctoriæ*, or of the *cynips quercus folii*, hymenopterous insects, which deposit their ova in the puncture. The nutgall gradually forms round the ovum. It is a hard spherical body, varying in size from

a quarter of an inch to a whole inch in diameter. The best gallnuts come from the Levant.

Gallnuts (in Latin, *Gallæ*) were known to the ancients, and were employed by them in medicine. But they seem to have had no accurate idea of their origin, as they considered them to be the fruit of the oak.

Though nutgalls had, for a long time, been employed in medicine, and though they were an essential ingredient in the black dye, and in the manufacture of ink, yet the first attempt to investigate their nature was by Dr Lewis, about the middle of the last century, during a set of experiments undertaken to ascertain the best method of making ink.* He detected in them a substance which strikes a *black* colour† with solutions of iron, and *coagulates* with isinglass.‡ But chemistry, in his time, had not advanced far enough to enable him to investigate, or to obtain this substance in a separate state. Deyeux was perhaps the first chemist who attempted to procure tannin in a separate state. He pointed it out as a peculiar *resinous* substance; but without assigning it a name.§ Nothing could be more inaccurate than his classing it with the resins, to which it bears no resemblance whatever. Sequin, soon after the commencement of the French Revolution, engaged in a series of experiments on the art of tanning leather;‖ during which, he discovered that *tannin* has the property of precipitating glue, from its solution in water, and of combining with the skins of animals. This led him to consider it as the essential constituent of the substances employed for the purpose of tanning skins. Hence the name *tannin* and *tanning principle*, by which it was distinguished by the French chemists. Proust was the first chemist who attempted to procure it in a separate state, and to investigate its properties.¶ Considerable light was thrown upon the constitution of astringent substances, and on their operation in tanning, by Sir H. Davy.** The number of experimenters upon nutgalls, and the methods proposed for extracting tannin from them in a state of purity, made during the course of the present century, is so great, that a bare enumeration of them would occupy a considerable space. And as very little light was thrown upon the nature of nutgalls by all these experimenters, numerous as they were, it seems unnecessary to enter into any further historical details.

In the year 1834, an exceedingly simple process for extracting tannin from nutgalls, in a state of purity, was discovered by M. Pelouze. This enabled him to ascertain its properties, and investigate its composition.†† And his experiments were speedily repeated and confirmed by M. Liebig.‡‡

* Philosophical Commerce of the Arts, p. 377. † Ibid. p. 346.
‡ Ibid. p. 387. § Ann. de Chim. xvii. 23. ‖ Ibid. xx. 38.
¶ Ibid. xxv. 225—xxxv. 32, and xlii. 89.
** Phil. Trans., 1803, p. 233, and Jour. of the Royal Institution, vol. ii.
†† Ann. de Chim. et de Phys. liv. 337.
‡‡ Ibid. lvii. 417, and Annalen der Pharmacie, x. 172.

Tannin may be obtained pure from nutgalls by the following process:—Into the mouth of a common caraff, or flask, fit, by grinding, a long, narrow glass vessel, fitted with a cork, or stopper, at the upper end. Fill the bottom of the long, narrow glass vessel, where it enters the flask, with a little cotton, and place above the cotton a quantity of nutgalls, in the state of fine powder, filling about half of the vessel. Pour over this a sufficient quantity of the common sulphuric ether of commerce to fill the rest of the vessel. Put in the stopper, and set the whole aside. Next day, we find in the flask two distinct layers of liquid. One, very light and very fluid, occupies the upper part; the other heavier, having a light amber colour, and the appearance of a syrup, occupies the bottom of the vessel. Pour the whole of these liquids into a funnel, stopping the bottom of the funnel with the finger. Let it remain at rest for a few minutes, till the two liquids separate from each other. Then allow the heavy liquid to fall into a capsule, and set the lighter portion aside, in order to recover the ether, of which it principally consists, by distillation. Wash the dense liquid two or three times with sulphuric ether; then dry it in a stove or, *in vacuo*, over sulphuric acid. Abundance of vapours of ether and a few of water are disengaged: the matter increases considerably in volume, and leaves a spongy residue, seemingly crystallized, very brilliant, and sometimes colourless, though most commonly having a slight tint of yellow. This substance is *tannin* in a state of purity.

If the ether be anhydrous, the heavy liquid does not make its appearance, unless we add a little water to the ether. By this process, from 35 to 40 parts of tannin are extracted from 100 parts of nutgalls.

Tannin being by far the most soluble in water of all the substances which nutgalls contain, when ether containing water is made to pass slowly through nutgalls in powder, the tannin combines with the water contained in the ether, and forms with it and a certain quantity of the ether a heavy syrup, which is gradually forced into the caraff by the superior strata of ether. Hence it happens, that the ether and the syrup are almost colourless, the colouring matters of the nutgalls remaining behind in the powder.

Pure tannin is colourless. Its taste is excessively astringent, without any bitterness. It has no smell. Water dissolves it in great quantity, and the solution reddens paper stained with litmus. It decomposes the alkaline carbonates with effervescence, and forms with most of the metallic solutions precipitates, which, in reality, are tannates. Salts containing only protoxide of iron are not rendered muddy by it, but it precipitates the salts of the peroxide of iron of a deep blue colour.

Alcohol and ether dissolve tannin, but in much less quantity than water. Indeed, M. Liebig found, that after being rendered anhydrous it dissolved in ether; but not if water be present.* M.

* Ann. de Chim. et de Phys. lvii. 417

Pelouze was unable to obtain it in the state of crystals, though he was at great pains, and made many and varied trials. When burnt on a platinum plate, it leaves no residue whatever.

A concentrated solution of tannin is precipitated white and abundantly by muriatic, nitric, phosphoric, and arsenic acids; but not by oxalic, tartaric, lactic, acetic, citric, succinic, or selenious acid. Neither does sulphurous acid gas produce any precipitate.

When nitric acid is heated with tannin it decomposes it rapidly, red vapours are given off abundantly, and oxalic acid is formed and deposited in crystals. Salts of cinchonina, quinina, brucina, strychnina, codeina, narcotina, and morphina, form with solution of tannin white precipitates, very little soluble in water; but very soluble in acetic acid.

When tannin is poured into a solution of gelatin in excess, a white opaque precipitate falls, which is soluble (especially when heated) in the liquid remaining. But when there is an excess of tannin in the liquid, the precipitate, instead of dissolving when heated, collects into a grey-coloured and very elastic membrane. In both cases the filtered liquor strikes a blue with the persalts of iron.

M. Pelouze adopted the following method, to determine whether tannin contains any gallic acid. A piece of skin depilated by lime, as is usual, when it is prepared for being tanned, is put into the solution of tannin, and agitated with it from time to time. The liquid is then filtered. The whole of the tannin is absorbed by the skin, and the filtered liquid, if no gallic acid be present, does not strike a blue with the persalts of iron. But if any gallic acid be present, though it amount only to one thousandth part, it gives a very perceptible shade of blue.

When alumina in the state of jelly is agitated with a solution of tannin, it absorbs it rapidly, and forms with it a very insoluble compound. For when the liquid in which the alumina has been agitated is filtered, it no longer strikes a blue with the persalts of iron.

M. Pelouze dried tannin in a temperature of 248°, and then subjected it to an ultimate analysis by means of oxide of copper.

Liebig analyzed it in the same way. The results obtained are the following:

	Pelouze.	Liebig.
Carbon	50·91	51·79
Hydrogen	4·16	4·12
Oxygen	44·93	44·09
	100·00*	100†

To determine the atomic weight of tannin, a quantity of tannate of lead, obtained by pouring acetate or nitrate of lead into an excess of tannin was washed and dried at the temperature of 248° and analyzed by combustion. Liebig obtained

* Ann. de Chim. et de Phys. liv. 343. † Ibid. lvii. 417.

Tannin . . .	65·9 or 27·05
Oxide of lead . .	34·1 or 14
	100·0

This gives us 27 for the atomic weight of tannin. Now, M. Pelouze considers

18 atoms carbon	= 13·5	or per cent.	50·71
9 atoms hydrogen	= 1·125	— —	4·22
12 atoms oxygen	= 12·0	— —	45·07
	26·625		100·00

proportions sufficiently near his analysis and the atomic weight found by him.

Liebig, on the contrary, considers the following atomic constitution as approaching nearer the truth :—

18 atoms carbon	= 13·5	or per cent.	50·95
8 atoms hydrogen	= 1	— —	3·77
12 atoms oxygen	= 12	— —	45·28
	26·5		100·00

The difference between these two determinations being only an atom of hydrogen, and Pelouze's numbers exceeding the hydrogen found, while Liebig's falls short of it, this circumstance weighs in favour of Liebig's view.

The peroxide of iron was combined with tannin by M. Pelouze, by pouring persulphate of iron into a solution of tannin, washing the precipitate and drying it at 248°. 1073 parts of this salt were found to contain 129 parts of peroxide of iron. Hence it was composed of

Tannin	36·58
Peroxide of iron . . .	5
	41·58

Now, if an atom of tannin weighs 26·5, it is obvious that this salt must be a sesquitannate of peroxide of iron. For sesquitannate would consist of

1½ atom tannin . . .	= 39·75
1 atom peroxide of iron .	= 5
	44·75

It is this sesquitannate which constitutes the basis of common ink. For the recent infusion of nutgalls contains very little gallic acid; and the gallate of peroxide of iron is rapidly decomposed when boiled in water.

The tannate of protoxide of antimony is a white gelatinous precipitate, very insoluble in water. It is also a sesquitannate composed of

1½ atom tannin . . .	39·75
1 atom protoxide of antimony	9·5
	49·25

According to Berzelius, tannate of potash and tannate of ammonia are very little soluble in water. They precipitate under the form of a white earth. They dissolve in boiling water, and partly precipitate as the liquid cools. When these precipitates are washed and dried, they have the appearance of a white earth, and are not altered by exposure to the atmosphere. But when they are kept moist, *extractive* is formed by the absorption of oxygen from the air. The tannate of soda has the same appearance but it is much more soluble.*

When a very dilute aqueous solution of tannin is exposed to the air, it gradually loses its transparency, and lets fall a grey precipitate in crystals consisting almost entirely of gallic acid. To obtain that acid in a state of purity, we have only to treat the boiling solution with a little animal charcoal. If we put the solution in a graduated glass tube in contact with oxygen gas, we shall find that the gas is gradually absorbed and replaced by an equal volume of carbonic acid gas, while after some weeks numerous crystalline needles of colourless gallic acid may be seen traversing the liquid.

If oxygen have not access to the solution of tannin, it may be kept a long time without undergoing any alteration. The same remark applies to the infusion of nutgalls. Chevreul kept it in a well-corked bottle for 3 years without any alteration.

Nutgalls give out to water about half their weight of soluble matter; about 40 per cent. of which is tannin. The gallic acid contained in the solution amounts only according to Richter to $3\frac{1}{2}$ per cent. of the weight of the nutgalls. Yet we know that when infusion of nutgalls is left to spontaneous decomposition, it yields about $\frac{1}{5}$th part of the weight of the galls of gallic acid. Hence it is obvious that the greater part of this acid formed during the spontaneous decomposition of infusion of nutgalls, is at the expense of the tannin. It is well known to chemists that the only way of getting gallic acid in considerable quantity from infusion of nutgalls, is to leave the infusion covered with paper to spontaneous decomposition.

SECTION XXX.—OF CATECHUIC ACID.

Catechu (*cachou* in French) has been an article of the *Materia Medica* for above a century. It is imported from India, and was at first distinguished by the name of *terra Japonica*, because it was considered as an earth, which was found in Japan. This opinion, stated by Pomet on the authority of Dr Caen, was so inconsistent with the characters of the substance that it fell under general discredit. And it came to be believed that catechu was extracted from the juice of a nut (*areca*, or betel nut). And agreeably to this opinion, Linnæus, in both editions of his *Materia Medica*, refers it to the *areca catechu*. The first accurate information upon the manufacture of catechu, was obtained from a paper published by

* Ann. de Chim. et de Phys. xxxvii. 389.

Mr Ker, entitled "Description of the plant from which the *terra Japonica* is extracted."* This gentleman, at that time assistant-surgeon to the civil hospital at Bengal, not only attended carefully to the process of the manufacturer, but actually repeated it himself.

The tree yielding catechu is the *Mimosa catechu* of Linnæus; the *acacia catechu* of modern botanists. It grows plentifully in the mountains of Kanhanna in Hindostan, and flowers in June. It seldom exceeds 12 feet in height, and 1 foot in the diameter of the stem. The catechu is obtained from the interior brown wood of the tree. After felling the trees, the manufacturer carefully cuts off the exterior white part of the wood. The interior coloured wood is cut into chips with which he fills a narrow mouthed unglazed earthen pot, pouring water upon them till he sees it among the upper chips. When this is half evaporated by boiling, the decoction without straining is poured into a flat earthen pot, and boiled to one third part. This is set in a cool place for one day, and afterwards evaporated by the heat of the sun, stirring it several times a-day. When it is reduced to a considerable thickness, it is spread upon a mat or cloth, which has previously been covered with the ashes of cow-dung. This mass is divided into quadrangular pieces by a string, and completely dried by turning them frequently in the sun till they are fit for sale.

This extract is called *cutt* by the natives. The term catechu is said to be a compound of the word *cate*, a tree, and *chu*, juice.

Catechu is used in India as a masticatory, it is employed also for tanning leather, and it constitutes an important dye-stuff. Considerable quantities of it are consumed in this country by the calico printers.

Two kinds of catechu come to this country; one from Bombay, the other from Bengal. They differ from each other more in their external appearance, than in their chemical composition—that from Bombay has a uniform texture, and a red brown colour, and its specific gravity is generally about 1·39. What comes from Bengal is generally more friable and less consistent. Its colour externally is like chocolate, but when broken it presents streaks of chocolate and reddish brown. Its specific gravity is about 1·28. The taste of both is the same; being astringent, and leaving in the mouth a sensation of sweetness. They are not altered by exposure to the air.† Davy found the two varieties composed of

	Bombay.	Bengal.
Tannin . . .	54·5	48·5
Peculiar extractive matter	34·0	36·5
Mucilage . . .	6·5	8·0
Insoluble matter, chiefly sand and lime . .	5·0	7·0
	100	100·0‡

* Med. Obs. and Inquiries, v. 151. † Davy, Phil. Trans. 1803, p. 252. ‡ Ibid. 259.

The tannin struck a black with the persalts of iron, while the extractive with the same salts gave a grass-green colour.

Buchner, in the year 1834, discovered the existence of an acid in catechu, to which he gave the name of *tannic acid* (*tanningensäure*). But that name having been already given to the substance usually denominated *tannin*, Buchner's name was changed into catechuic acid. In 1835 some experiments on the mode of obtaining this acid in a state of purity, were made by Dahlström, an account of which has been given by Berzelius in his *Jahrsbericht*, No. 14, p. 235. In the year 1836, a set of experiments on this acid was published by Mr L. F. Svanberg, in the *Memoirs of the Stockholm Academy of Sciences.**

Buchner employed the following method to procure catechuic acid. Eight ounces of Bombay catechu (Bengal catechu is not so productive) were reduced to a very fine powder, and macerated during eight days in four times their weight of water, taking care to agitate frequently during the whole time that the maceration continued. The solution, after being left four or five days to become clear, was drawn off. The undissolved residue was treated as before with four times its weight of cold water. This process was repeated three or four times more, employing only twice the weight of the powder of water instead of four times. The undissolved residue was finally dissolved in eight times its weight of boiling water. The boiling hot solution containing the catechuic acid and the tannin was treated while boiling hot with a very dilute solution of acetate of lead, till the liquid (a little being filtered on purpose) has only the colour of Rhinewine, a proof that the colouring matter has been thrown down. The liquid is now filtered while boiling hot as rapidly as possible, because the acid begins to be deposited as soon as the liquid cools. At the temperature of 32° it is deposited immediately; but at the summer temperature, some hours elapse before it begins to appear. The acid is deposited in the state of small white grains. After 12 hours it is collected on the filter, dissolved in boiling water, clarified by white of egg, and filtered while boiling hot into a flask that can be shut so as to be air tight, because the acid becomes coloured when exposed to the air. When the liquid has been filtered the flask is to be filled with water, corked up, slowly heated, and then allowed to cool slowly. The acid is deposited during the cooling.

As the catechuic acid obtained in this way was still impure, Svanberg dissolved it in hot water and precipitated it completely by acetate of lead. The catechuate of lead thus obtained was decomposed by sulphuretted hydrogen. The catechuic acid was separated from the sulphuret of lead by hot water, and thus the whole of the colouring matter was left behind. When the solution cooled, the catechuic acid was deposited perfectly white. But if it be exposed while moist to the air, or if we attempt to wash it on the filter, it

* See a translation of the paper in Poggendorf's Annalen, xxxix. 161.

becomes yellow. It must therefore be rapidly squeezed between folds of paper, and dried, *in vacuo*, over sulphuric acid. The water employed to dissolve it from the sulphuret of lead, must not be boiling hot, and it must not be employed in so small quantity as to become completely saturated; for in both cases a portion of the colouring matter is again redissolved. This is prevented by applying the water in sufficient quantity, and at a temperature not exceeding 194°.

Catechuic acid is very feeble, not stronger in its acid properties than common sugar. When boiled with carbonate of lime, it does not expel the carbonic acid. When it is dissolved in carbonate of potash no carbonic acid is disengaged, until the acid has been added in such quantity that a portion of it crystallizes on the cooling of the liquid.*

When catechuic acid is put into a glass vessel filled with ammoniacal gas, that gas is absorbed, and the acid combines with it; but the union is so slight that the whole gas makes its escape if we put the salt into a vacuum, or if we apply heat. If we dissolve in cold water catechuic acid, combined with ammonia, after the alkali has been expelled by placing it *in vacuo*, the catechuic acid almost immediately resumes its former state, and falls to the bottom under the form of a white powder. If we allow the access of air to the compound of catechuic acid and an alkali, oxygen gas is absorbed, and the acid becomes red, and at last black.

Catechuic acid is not precipitated by gelatin. Acetate of lime gives with it a white precipitate, which is not soluble even in hot water; but like all the compounds of this acid it becomes coloured when exposed to the air.

Acetate of barytes is neither precipitated by catechuic acid, nor by its compound with ammonia. Acetate of copper is not precipitated by the uncombined acid; but the solution becomes brown and seems to be brought into the same state as when treated with caustic potash with access of air. If ammonia be added to the acid liquid, a dark brown precipitate falls. When acetate of copper is mixed with a hot solution of catechuic acid, a brown precipitate falls, which soon becomes black.

Nitrate of silver is not precipitated by catechuic acid. But if a very little ammonia be added a black precipitate falls. Hot solution of catechuic acid throws down the same precipitate—it is redissolved in dilute nitric acid, and in caustic ammonia.

Potash-chloride of gold is precipitated of a reddish brown colour by catechuic acid. The precipitate dissolves with a fine yellow colour when more water is added. When the mixture is heated, the gold is reduced and falls down light coloured. Soda-chloride of platinum is not precipitated by this acid; but the solution becomes

* The experiment must be made out of the contact of air, otherwise the acid will be changed into japonic acid. The best method is to fill the vessel containing the liquid with hydrogen gas.

yellow, and when heated the platinum is reduced, though slowly, and a small flocky brown matter falls down along with it.

Acetate of lead is thrown down white by catechuic acid. The precipitate is dissolved completely when we attempt to wash it on the filter. By exposure to the air it becomes speedily yellow. To prevent this it must be rapidly dried between folds of blotting paper, and then placed in a vacuum over sulphuric acid. This salt was analyzed by M. Svanberg, and found composed of

Catechuic acid . .	2316 or 16·91
Oxide of lead . .	1917 or 14
	4233

This makes the atomic weight of catechuic acid 16·91, or very nearly 17.

He analyzed the acid by heating it with oxide of copper, and found the constituents to be

Carbon	61·666 or 15 atoms	= 11·25	or per cent.	62·50
Hydrogen	4·720 or 6 atoms	= 0·75	— —	4·16
Oxygen	33·614 or 6 atoms	= 6·00	— —	33·34
		18		100·00

But the atomic weight in this case is too high. The reason, doubtless, is, that the catechuic acid, in the state in which it was analyzed by Svanberg, contained an atom of water. The anhydrous acid is, doubtless, composed of

15 atoms carbon . .	= 11·25
5 atoms hydrogen . .	= 0·625
5 atoms oxygen . .	= 5
	16·875

The true atomic weight is 16·875, a number almost coinciding with that derived from the analysis of catechuate of lead.

SECTION XXXI.—OF JAPONIC ACID.*

When catechuic acid is digested with caustic potash, in contact with the air, it absorbs oxygen gas, and the colour changes first to rose red, then to deep red, and finally to black. The same alteration takes place when ammonia is substituted for potash. By this absorption of oxygen, the catechuic acid is changed into *japonic* acid. Svanberg digested catechuic acid for several days in an excess of caustic potash, assisted by heat, taking care that the air had free admission. The alkaline liquor was now treated with an excess of acetic acid, evaporated almost to dryness, and digested in alcohol. The acetate of potash was dissolved, and a *superjaponate* of potash remained behind. To purify this last salt completely, it must be repeatedly digested in alcohol. It is then to be dissolved in water, and muriatic acid added in the smallest possible excess. The japonic acid precipitates, only a very small portion of it remaining in

* Poggendorf's Annalen, xxxix. 171.

solution. The greater the excess of muriatic acid, the greater quantity of japonic acid will be dissolved.

Japonic acid is black, and dissolves very slightly in cold water—almost not at all, indeed, if it has been well dried. When fresh prepared, and still moist, it dissolves better in hot water, and, as the solution cools, the acid is deposited in black grains. Its aqueous solution reddens litmus paper. It is insoluble in alcohol. Acetic acid does not throw it down from its solutions; but when japonate of potash is digested with an excess of acetic acid, and the whole evaporated to dryness, a superjaponate of potash is obtained.

The japonates do not crystallize, but dry into hard masses. We obtain neutral japonate of potash when we boil the acid in a very concentrated state with caustic potash, and then remove the excess of potash by alcohol. It gives, with chlorides of barium, calcium aluminum, glucinum, and yttrium, bulky black precipitates, not soluble in dilute nitric acid. With sulphate of copper, it gives a very dark green precipitate; with nitrate of silver, a black; but it whitens when washed with water, in which it is somewhat soluble. After being dried at 212°, it is not decomposed by muriatic acid; but caustic potash dissolves the acid, and leaves the oxide of silver.

Svanberg analyzed japonate of silver, and found it composed of

Japonic acid . .	4757 or 13·49
Oxide of silver . .	5112 or 14·5
	9869

According to this analysis, the atomic weight of japonic acid is 13·49.

He analyzed the acid by means of oxide of copper and obtained

Carbon	61·34 or 12 atoms	= 9	or per cent.		61·54
Hydrogen	4·25 or 5 atoms	= 0·625	—	—	4·27
Oxygen	34·41 or 5 atoms	= 5·0	—	—	34·19
	100·00	14·625			100·00

The atomic weight is 14·625, or more than that resulting from the analysis of japonate of silver by 1·125, which is equivalent to an atom of water. Anhydrous japonic acid, therefore, is a compound of

12 atoms carbon . . .	= 9
4 atoms hydrogen . .	= 0·5
4 atoms oxygen . . .	= 4
	13·5

When we compare catechuic acid with japonic acid, we find the difference as follows:—

Catechuic acid . .	C^{15} H^{5} O^{5}
Japonic acid . . .	C^{12} H^{4} O^{4}
	C^{3} H O

This is equivalent to an atom of water, and three atoms of carbon.

From this it would appear, that the oxygen gas absorbed by the catechuic acid, when it is converted into japonic acid, unites with the carbon. Whether carbonic acid be formed has not been ascertained, but it is probable. In fact, the ratios between the atoms in both compounds is the same. We might consider the composition as identical, if it were not for the difference of the atomic weights.

SECTION XXXII.—OF RUBINIC ACID.*

If we dissolve catechuic acid in carbonate of potash, and leave the solution exposed to the air without the application of heat, it becomes *red*, and dries into a hard, uncrystalline mass, which dissolves in water with great difficulty. In this state, it is a *rubinate of potash*, mixed with a quantity of carbonate of potash. If we apply heat during the evaporation, the acid blackens, and the salt is converted into japonate of potash. The evaporation, when we wish to obtain rubinic acid, must be spontaneous, or conducted in *vacuo*, over sulphuric acid. The rubinate of potash is to be reduced to a very fine powder, mixed with water, and well shaken, a long time being required before the water is saturated with the salt. The dissolved portion is filtered from the undissolved portion, and saturated with acetic acid, in order to convert the carbonate of potash into acetate. Care must be taken to add as small an excess of acetic acid as possible, because it dissolves some of the *rubinic acid*. The solution must be rapidly filtered from the undissolved portion. For, if air be admitted, the rubinic is always converted into japonic acid. The solution being mixed with strong alcohol, the rubinate of potash precipitates. To obtain it pure, it should be washed with alcohol.

Rubinate of potash thus obtained, throws down the earthy and metallic salts of a red colour. The precipitates generally redissolve during the washing, when they are freed from the excess of the precipitating salts. From Svanberg's experiments it does not appear possible to obtain rubinic acid in a disengaged state. When a solution of rubinate of potash is mixed with muriatic acid, the acid which falls possesses the characters of japonic acid.

M. Svanberg analyzed rubinate of silver, and found it composed of

Rubinic acid . .	32·81 or 23·56
Oxide of silver . .	20·19 or 14·5
	53·00

This makes its atomic weight 23·56.

He analyzed a given quantity of rubinate of silver by means of oxide of copper, and found the acid composed of

Carbon	58·20 or 18 atoms	= 13·50	or per cent.	58·07
Hydrogen	3·41 or 6 atoms	= 0·75	— —	3·22
Oxygen	38·39 or 9 atoms	= 9·00	— —	38·71
	100	23·25		100·00

* Poggendorf's Annalen, xxxix. 171.

If this analysis be accurate, rubinic acid bears no analogy either to catechuic or japonic acids, as will be obvious from the following comparison :—

Catechuic acid . .	C^{15} H^{5} O^{5}
Japonic acid . . .	C^{12} H^{4} O^{4}
Rubinic acid . . .	C^{18} H^{6} O^{9}

SECTION XXXIII.—OF ULMIC ACID.

In the account of this acid given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 105), the analysis of it by M. P. Boullay is inserted. It has been since obtained by M. Malagutti, by boiling sugar in diluted acids. He analyzed it, dried in the temperature of 392°, and obtained

Carbon	57·48
Hydrogen	4·76
Oxygen	37·36
	100·00*

Numbers approaching nearly those of Boullay.

M. Malagutti analyzed ulmate of silver, and obtained

Ulmic acid . . .	74 or 41·27
Oxide of silver . .	26 or 14·5
	100

Ulmate of copper was composed of

Ulmic acid . .	89·2 or 41·29
Oxide of copper . .	10·8 or 5

If the salt be neutral, those numbers give us 41·28 for the atomic weight of ulmic acid. This deviates but little from Boullay's previous analysis of ulmate of copper.

If we adopt Malagutti's formula, we have for the composition of ulmic acid,

30 atoms carbon	= 22·5	or per cent.	57·15
15 atoms hydrogen	= 1·875	— —	4·76
15 atoms oxygen	= 15·0	— —	38·09
	39·375		100·00

This constitution agrees exactly with the previous experiments of Boullay.

M. Malagutti has found, that when the boiling of ulmic acid with an acid is continued, a black insoluble matter is deposited, which he calls ulmin. In its composition it agrees exactly with ulmic acid.

* Jour. de Pharm. xxi. 455.

CHAPTER III.

OF OILY ACIDS.

These acids are so called, because they are formed from oils or fat, and enter into the composition of soaps; or because they possess many of the characters of oils. They are 23 in number, and were first investigated by M. Chevreul, who devoted ten years to the assiduous study of the chemical properties of fixed oils and fats. The following table exhibits their names and constituents, or at least, their ratios:—

1	Butyric	C^8	H^5	O^3	
2	Smilacic	C^8	$H^{7\frac{1}{2}}$	O^3	
3	Phocenic	C^{10}	$H^{7\frac{1}{2}}$	O^3	
4	Hydrospiroilic	C^{12}	H^6	O^4	
5	Caproic	C^{12}	H^{10}	O^3	
6	Spiroilic	C^{12}	H^5	O^8	
7	Chlorophenisic	C^{12}	H^3	O^2	Chl^3
8	Chlorophenesic	C^{12}	H^3	O^2	Chl^2
9	Oenanthic	C^{14}	H^{13}	O^2	
10	Anchusic	C^{17}	H^{10}	O^4	
11	Roccellic	C^{17}	H^{16}	O^4	
12	Capric	C^{18}	H^{14}	O^3	
13	Ricinic	C^{24}	H^{24}	O^4	
14	Santonin	C^{60}	H^{36}	O^{12}	
15	Stearic	C^{72}	H^{68}	O^4	
16	Oleic	C^{70}	H^{62}	O^7	
17	Metoleic	C^{70}	H^{64}	O^9	
18	Hydroleic	C^{70}	H^{65}	O^{10}	
19	Margaric	C^{70}	H^{69}	O^8	
20	Metamargaric	C^{70}	H^{67}	O^6	
21	Hydromargaric	C^{70}	H^{70}	O^9	
22	Hircic } Not yet analyzed.				
23	Elaiodic }				

Several of these acids have been described in the *Chemistry of Inorganic Bodies*, (vol. ii. pp. 122 to 139). I shall here give an account of the new oily acids which have been discovered since the publication of that work, and of the new views respecting some of the acids of Chevreul, which have resulted from later experiments.

SECTION I.—OF MARGARIC ACID.

When margaric acid is mixed with a fourth part of its weight of quicklime, and distilled in a retort, there comes over first a small quantity of water. Then a soft matter, which, when pressed between the folds of blotting paper, gives out oil, and a white substance remains, the properties of which will be immediately described.

The last portions of the acid undergo a more complete decomposition, for the matters pass over coloured and empyreumatic, and there remain behind, in the retort, lime, and carbonate of lime, blackened by a small quantity of charcoal. Forty parts of margaric acid, thus treated, yielded 28 parts of solid matter, of a light-yellow colour, which, when exposed to pressure, left 22 parts of a hard white solid matter, to which M. Bussy, to whom we are indebted for these experiments,* has given the name of *margarone*. To obtain it pure, it ought to be repeatedly dissolved in alcohol, and allowed to separate by crystallization.

Margarone thus purified is white, brilliant, and has a pearly lustre. It melts when heated to 170°, and crystallizes confusedly on cooling, bearing in that state some resemblance to margaric acid or spermaceti. It is a non-conductor of electricity, and becomes electric by friction or by pressure. When heated in a retort it boils, and may be distilled over without alteration, and without leaving any residue. It burns with a bright flame, and without smoke.

It dissolves in 50 times its weight of boiling alcohol of the specific gravity 0·836. But the greater part is deposited when the alcohol cools. Water also throws it down from this solution. It is more soluble in alcohol of 0·817, 3 parts dissolving in 20 of the alcohol. The solution becomes solid on cooling. Ether, at the boiling point, dissolves about $\frac{2}{3}$ths of its weight of it. But the greatest part precipitates when the solution cools. Acetic ether, and likewise oil of turpentine, dissolve it abundantly. It combines with camphor in all proportions.

When boiled with concentrated potash ley, it undergoes no alteration, being incapable of forming a soap. Sulphuric acid deepens its colour, and decomposes it with the disengagement of sulphurous acid. One part of margarone gently heated with two parts of sulphuric acid becomes first red, then brown, then black, and is soon converted into a mass of charcoal. Nitric acid acts on it very feebly, even when assisted by heat. When exposed in a tube to a current of dry chlorine gas, and under the influence of a gentle heat, it is transformed completely into a colourless transparent viscid liquid.

Margarone has considerable resemblance to paraffin. But paffin melts at 110°$\frac{5}{4}$, and is not altered by sulphuric acid.

Margarone was analyzed by M. Bussy by means of oxide of copper. He found it composed of

Carbon	82·22
Hydrogen	13·51
Oxygen	4·27
	100·00

Now, according to the analysis of M. Chevreul, margaric acid is composed of

* Ann. de Chim. et de Phys. liii. 398.

Carbon	79·053
Hydrogen	12·010
Oxygen	8·937
	100·00

And he considers its constitution to be C^{35} H^{32} O^3. Now, the numbers obtained by Bussy for margarone, give us for its constitution C^{34} H^{32} O, so that it differs from margaric acid by wanting an atom of carbonic acid.

The atom of margarone is	C^{34} H^{32} O
The atom of carbonic acid is	C O^2
Making together an atom of margaric acid =	C^{35} H^{32} O^3

When two atoms of margarone are distilled with caustic potash they are deprived of an atom of carbonic acid, and converted into paraffin. But the volatility of margarone prevents this change from being complete.

SECTION II.—OF STEARIC ACID.

When stearic acid is distilled with quicklime, it yields a substance which M. Bussy* has distinguished by the name of *stearone*, very analogous to margarone, but less fusible. Its constituents, according to Bussy's analysis, are

Carbon	84·78
Hydrogen	13·77
Oxygen	1·45
	100·00

Now, according to the analysis of Chevreul, stearic acid is C^{70} H^{67} O^5. If we deprive it of two atoms carbonic acid, C^2 O^4, we have C^{68} H^{67} O, which represents exactly the numbers resulting from the analysis of Bussy. The lime, therefore, by retaining two atoms of carbonic acid, converts the stearic acid into *stearone*.

Stearone melts when heated to 187°. In other respects it resembles margarone. From the great combustibility and high fusing points of margarone and stearone, they would answer admirably for candles. They could be obtained directly by the distillation of tallow.

When *oleic* acid is distilled with quicklime, it yields a liquid incapable of being converted into soap, and possessing analogous properties with the preceding. M. Bussy has given it the name of *oleone;* but has not succeeded in freeing it completely from foreign matter, which prevented him from studying its properties.†

SECTION III.—OF METAMARGARIC ACID.

When olive oil is treated with half its weight of concentrated sulphuric acid, added in small quantities at a time, taking care to

* Ann. de Chim. et de Phys. liii. 410. † Ibid liii. 411.

keep the liquid cool, and the whole carefully mixed, the three constituents of the oil combine with the acid, and form three new acids which have received the names of *sulphoglyceric*, *sulphomargaric*, and *sulpho-oleic acids*.*

When water is added, the matter is divided into two portions. The sulphoglyceric acid, with the excess of the sulphuric acid dissolves in the water, while the sulphomargaric and sulpho-oleic acids remain undissolved, as long as any excess of sulphuric acid is present. When the aqueous solution is saturated with lime, to separate the excess of sulphuric acid, sulphoglycerate of lime is formed.

The sulphomargaric and sulpho-oleic acids remain in the state of a syrup, and may be freed from all excess of sulphuric acid, by washing them once or twice in water, in which they are insoluble, as long as any such excess remains. This excess being removed, the two compound acids dissolve very readily in water. The solution of these two acids undergoes spontaneous decomposition in 24 hours; the two fatty acids separating, and the sulphuric acid remaining dissolved in the water. When these acids thus separated from the sulphuric, are exposed to pressure between folds of blotting paper, the *meta-oleic* acid is easily separated from the *metamargaric*. To obtain this last acid in a state of purity, we must dissolve it in boiling alcohol. It is deposited in crystals when the solution cools. These crystals are partly in shining plates, partly in round warts.

Metamargaric acid, thus obtained, is insoluble in water, but soluble in alcohol and ether. It melts at 122°; when cooled slowly it crystallizes in confused shining needles.

M. Fremy analyzed this acid and obtained

Carbon	73·27 or 70 atoms	= 52·5	or per cent.		74·73
Hydrogen	12·74 or 70 atoms	= 8·75	—	—	12·45
Oxygen	13·99 or 9 atoms	= 9	—	—	12·82
		72·25			100†

It contains an atom of water more than margaric acid.

Fremy analyzed the metamargarate of lead and of silver, and found the acid in both composed of

70 atoms carbon . .	= 52·5
67 atoms hydrogen . .	= 8·375
6 atoms oxygen . .	= 6
	66·875

Differing from the crystallized acid by containing three atoms of water less. This he considers as equivalent to twice an atom of margaric acid. In that case the atoms of hydrogen in margaric

* Fremy, Ann. der Pharmacie, xx. 50.

† These numbers do not correspond with the analysis deduced from M. Fremy's data. I have little doubt that typographical errors exist in the statement of the analysis, and that the formula is the correct statement.

acid, instead of 32, which is the result of the analysis of Chevreul, must be $33\frac{1}{2}$.

M. Fremy obtained metamargarate of potash, by dissolving the salt in alcohol, and leaving it to spontaneous crystallization. It was deposited in hard grains very similar in appearance to margarate of potash. He found its composition precisely the same as that of the two preceding salts.

This salt is but little soluble in cold, but pretty soluble in boiling water. It melts before it undergoes decomposition.

Metamargarates of soda and ammonia, crystallize in the same way as the salt of potash. The remaining metamargarates are insoluble in water.

SECTION IV.—OF META-OLEIC ACID.

This acid, like the preceding, separates from the sulpho-oleic acid by spontaneous decomposition, and it is readily freed from metamargaric acid by exposure to a cold of $26°\frac{1}{2}$. It is usually liquid, has a yellow colour, is insoluble in water, soluble in ether, and very sparingly soluble in alcohol. This last property distinguishes it from oleic acid, which dissolves in alcohol in every proportion.

This acid was analyzed by Fremy, who obtained

Carbon	74·77 or 70 atoms	= 52·5	or per cent.	75·54
Hydrogen	11·96 or 64 atoms	= 8	— —	11·51
Oxygen	13·27 or 9 atoms	= 9	— —	12·95
	100	69·5		100

Fremy considers oleic acid to consist of C^{70} H^{62} O^{7}. So that meta-oleic acid differs from it by containing two additional atoms of water.

When combined with bases, it loses one atom of water; the formula for it in that state being, according to Fremy, C^{70} H^{63} O^{8}, and its atomic weight 68·375.

M. Fremy was unable to obtain any of the meta-oleates in a crystallized state. The only soluble salts among them are the meta-oleates of potash, soda, and ammonia, and they cannot be made to crystallize.

SECTION V.—OF HYDROMARGARIC ACID.

When the mixture of sulphomargaric and sulpho-oleic acids is decomposed at a temperature of 212°, there are two new fatty acids formed, which Fremy has distinguished by the names of *hydromargaric* and *hydro-oleic acids*. When the solution of sulphomargaric and sulpho-oleic acids is boiled, the two new acids separate in a few minutes, and by exposing the mixture of the two new acids to pressure, at a temperature of from 68° to 86°, the hydro-oleic acid is separated, the remaining hydromargaric acid is freed from all the hydro-oleic acid by repeated solutions in alcohol and crystallizations.

Hydromargaric acid, thus obtained, is white, insoluble in

water, soluble in alcohol and ether, and crystallizes from these solutions in warty nodules. It melts at 140°, and concretes on cooling into an opaque crystalline mass, which cannot be distinguished from metamargaric acid subjected to the same treatment. Fremy considers the following formula as indicating the constitution of this acid.*

70 atoms carbon	=52·5	or per cent.	73·55
71 atoms hydrogen	= 8·875	— —	12·43
10 atoms oxygen	=10·0	— —	14·02
	71·375		100·00

He analyzed the hydromargarates of lead and silver, and found the acid in them composed of

70 atoms carbon . . .	= 52·5
70 atoms hydrogen . .	= 8·75
9 atoms oxygen . . .	= 9
	70·25

Or the very same as the crystals of metamargaric acid. Thus it appears that hydromargaric acid differs from metamargaric acid by containing an additional atom of water.

Hydromargarates of potash, soda, and ammonia, crystallize, and are composed as the two preceding salts.

When this acid is distilled, it undergoes decomposition, and pure metamargaric acid passes over, no doubt with the evolution of water.

SECTION VI.—OF HYDRO-OLEIC ACID.

It has been already stated, that this acid is obtained when sulpho-oleic acid is decomposed at the temperature of 212°. It must be kept for some time in a cold temperature to cause it to deposit the hydromargaric acid, with which it is mixed.

When pure it is somewhat coloured, and has an etherial smell. It is insoluble in water, but soluble in alcohol in every proportion. It is composed, according to Fremy, of

70 atoms carbon	= 52·5	or per cent.	74·34
65 atoms hydrogen	= 8·125	— —	11·50
10 atoms oxygen	= 10	— —	14·16
	70·625		100

When combined with oxide of lead or of silver, it loses an atom of water, being then composed of C^{70} H^{64} O^{9}, which is the constitution of meta-oleic acid.

The salts of this acid have a great resemblance to the meta-oleates of potash, soda and ammonia, but are much more soluble in water than the corresponding meta-oleates.

* He has given us the results of his analysis; but his results are not intelligible; probably from typographical errors in the numbers.

This acid is decomposed with precisely the same phenomena as the meta-oleic acid.

When the distillation of hydro-oleic acid is carefully conducted, and the products preserved, there passes over a pretty regular current of pure carbonic acid, and there is found in the receiver a small quantity of water, over which floats an oily stratum. This stratum is composed of two carbo-hydrogen liquids, having the same composition with olefiant gas. One of these boils at 131°, the other at 230°. Fremy has called the first of these substances *olein*, the last *elain*.

When the oily stratum is distilled at 266°, the olein and elain pass over, and thus are freed from an empyreumatic oil with which they were mixed. They were then agitated with a dilute solution of caustic potash, to free them from any trace of oily acid that might be present. The whole was then digested with chloride of calcium. Then by distilling at 131°, the olein came over, and it was purified by repeated distillations. The elain was rendered pure in the same way.

Olein is white, very liquid, and lighter than water. It has a penetrating arsenical and nauseous smell. It is very combustible, and burns with a flame having a greenish tinge. It is scarcely soluble in water, but very soluble in alcohol and ether. Sulphuric acid has no sensible action on it. Its boiling point seems to be 131°. Its vapour appears to be poisonous, as a bird exposed for some time to it, fell down dead.

Fremy found the specific gravity of its vapour 2·942. It was analyzed by him and found composed of

Carbon	85·72
Hydrogen	14·73
	100·45

This approaches nearly

1 atom carbon . .	= 0·75
1 atom hydrogen . .	= 0·125
	0·875

But the vapour weighs 2·942. Now

6 volumes carbon weigh .	2·5
6 volumes hydrogen gas .	0·4166
	2·9166

It appears from this that olein vapour is composed of 6 volumes carbon and 6 volumes hydrogen, condensed into one volume, consequently it must be a compound of

6 atoms carbon . .	= 4·5
6 atoms hydrogen . .	= 0·75
	5·25

So that its atomic weight is 5·25

Olein combines cold with chlorine, and forms a liquid chloride having an etherial smell.

Elain is white, insoluble in water, less soluble in alcohol than olein, and has a penetrating smell, not differing much from that of olein. It burns with a fine white flame, and boils at 230°. It is lighter than water, and is not attacked by sulphuric acid. The specific gravity of its vapour is 4·488.

According to Fremy's analysis it is composed of

1 atom carbon . .	= 0·75
1 atom hydrogen . .	= 0·125
	0·875
But 9 volumes carbon vapour weigh .	3·7500
9 volumes hydrogen gas . . .	0·6246
	4·3746

From this it is evident that the vapour consists of 9 volumes carbon and 9 volumes hydrogen, condensed into 1 volume, and that liquid elain is a compound of

9 atoms carbon . .	= 6·75
9 atoms hydrogen . .	= 1·125
	7·875

Elain combines with chlorine, and heat is evolved. This chloride is heavier than water and is insoluble in that liquid. It has an etherial smell, and burns with an intense green flame.

According to Fremy's analysis it is composed of

5 atoms carbon . .	= 3·75
5 atoms hydrogen . .	= 0·625
1 atom chlorine . . .	= 4·5
	8·875

If this analysis be correct, it is clear that the chloride does not consist of a compound of 1 atom elain with 1 but with 2 atoms of chlorine.

SECTION VII.—OF ANCHUSIC ACID.

This name was given in 1818, by M. Pelletier, to the colouring matter of the *anchusa tinctoria*, because it possesses the properties of an acid. It has got the name of *orcanette* from the French dyers.

According to John, this colouring matter, which is *red*, and is insoluble in water, may be extracted pure from the bark of the root by digesting it in ether. When the ether is distilled off, the colouring matter remains in the form of a deep red resinous-looking mass, rather heavier than water.

Anchusic acid is analagous to the other fatty acids. It is insoluble in water, but soluble in alcohol and ether. What is very remarkable, the neutral compounds which it forms with the alkalies and alkaline earths are also soluble in alcohol and ether. The

anchusate of magnesia possesses this property in a remarkable degree.

Anchusic acid may be sublimed. When cautiously heated, it emits vapours of a violet-red colour, having some resemblance to those of iodine. These vapours are extremely irritating, and have some analogy to those of selenium in combustion. These vapours condense, when cooled, into very light flocks. The point at which anchusic acid undergoes decomposition is not much higher than that at which it sublimes. On this account it is difficult to sublime it in any considerable quantity.

The constituents of this acid, according to the analysis of Pelletier, are

Carbon	71·178 or 17 atoms	=	12·75	or per cent.	70·84
Hydrogen	6·826 or 10 atoms	=	1·25	— —	6·94
Oxygen	21·996 or 4 atoms	=	4	— —	22·22
	100·000		18		100

These numbers of course, in the present state of our knowledge, can only indicate the ratios of the atoms of the three constituents of anchusic acid.*

SECTION VIII.—OF ROCCELLIC ACID.

This acid was discovered by Dr Heeren in the *Rocella tinctoria*, and described by him in Schweigger-Siedel's Jahrbuch.† He sent a specimen of it to M. Liebig, who subjected it to a chemical analysis.‡ The method of procuring this acid is as follows:—

The lichen is digested in a concentrated ammoniacal solution till every thing soluble in that alkali is taken up. The solution is then diluted with water and mixed with a solution of chloride of calcium. A precipitate falls, which must be washed in water, and then decomposed by muriatic acid. When sulphuric ether is digested upon the precipitate a pure solution of roccellic acid is obtained. By distilling off the ether we procure the acid free from all foreign matter.

Roccellic acid is a solid fatty-looking matter. When melted by heat it congeals again at 251° into a crystalline mass. It is insoluble in water, whether cold or hot. It dissolves in less than twice its weight of boiling alcohol, and crystallizes, as the solution cools, in short needles. It is also very soluble in ether, and separates from the solution in short crystals, which, viewed under the microscope, have the form of square tables. They do not lose any water when fused. When roccellic acid is distilled, it undergoes partial decomposition. When strongly heated in the open air, it catches fire and burns like tallow.

Dr Heeren, from the analysis of several roccellates, has determined the atomic weight of the acid to be 18·82.

Liebig subjected the acid to an ultimate analysis, by means of oxide of copper, and obtained

* Ann. de Chim. et de Phys. li. 191.

† Vol. lix. p. 347. ‡ Poggendorf's Annalen, xxi. 31.

Carbon	67·04 or 17 atoms =	12·75 or	per cent.	68
Hydrogen	10·75 or 16 atoms =	2	— —	10·67
Oxygen	22·21 or 4 atoms =	4	— —	21·33
	100·00	18·75		100·00

As the theoretical results do not quite agree with the analysis, it is obvious that farther researches will be necessary to settle the exact atomic weight and the atomic constituents of this fatty acid.

Roccellate of potash crystallizes in fine plates, similar to those of the acid. Its aqueous solution froths like that of soap.

Roccellate of ammonia is very soluble in water, and, when evaporated to dryness, leaves the salt in a state similar to varnish. Its solution also froths, when agitated, like that of soap. It dissolves a considerable excess of acid when assisted by heat, forming a super-salt; but the excess is again deposited when the liquid cools.

Roccellate of lime is a white insoluble powder. It is composed, according to the analysis of Heeren, of

Roccellic acid . .	0·847 or 18·64
Lime . . .	0·159 or 3·5
	1·006

This gives us 18·64 for the atomic weight of the acid.

SECTION IX.—OF CHLOROPHENISIC AND CHLOROPHENESIC ACIDS.

These acids were discovered and examined by M. Laurent in 1836. They were named by him from a supposed base which he called *phene* (from φαινω, *I shine*), from a supposition that it exists in the oil gas which was used for lighting the streets.*

These acids were obtained by M. Laurent in the following manner:—A quantity of coal tar was distilled, and the process stopped when the matter in the retort began to get viscid. Through the liquid that came over *(coal naphtha)* a current of chlorine gas was passed for a whole day. The liquid was then cooled down to 14°. Numerous crystals of naphthaline fell, which were separated by the filter. Chlorine gas was transmitted during two days through the liquid which had passed through the filter. It became thick, and being cooled down to 32°, by enclosing it in ice, muriate of *chloro-naphthalese* fell to the bottom. The liquid oil was decanted off this muriate, and subjected to distillation. It swelled up greatly owing to the disengagement of chlorine gas. An oil distilled over, accompanied by vapours of muriatic acid. Towards the end of the process the oil in the retort became black and swelled up to twice or thrice its original bulk. When this took place the distillation was stopped.

The oily liquor, thus obtained, was introduced into a large flask, concentrated sulphuric acid was added to it by degrees, and the whole well agitated after every addition; and this addition and agitation was continued till the evolution of muriatic acid, at first abundant, ceased entirely.

* Ann. de Chim. et de Phys. lxiii. 27.

The liquid being left at rest, the sulphuric acid collected at the bottom of the flask, and was withdrawn by a sucker, and the oil was washed with a great deal of water.

The sulphuric acid had acquired a red colour, and, when saturated with an alkali, deposited a substance having a most insupportable smell.

The oil, thus purified by sulphuric acid and water, was introduced into a large globular glass vessel, and liquid ammonia was poured upon it. The whole concreted into a white semisolid mass, and, at the same time, the temperature was slightly increased.

When this semisolid matter was boiled with a great quantity of water it was mostly dissolved, and the solution was filtered while boiling hot. On cooling, it deposited crystalline grains. These grains consisted of a mixture of *chlorophenesate* and *chlorophenisate* of ammonia, accompanied by a red colouring matter.

The solid matter being dissolved in water, and nitric acid, diluted with five or six times its weight of water, being added till the liquid began to get muddy, the whole was passed through the filter, which retained a brown-coloured matter. A slight excess of nitric acid being added to the filtered liquid, a white gelatinous precipitate fell. It was washed, pressed between the folds of blotting paper, dried and distilled. What came over was a mixture of *chlorophenesic* and *chlorophenisic* acids.

To separate these acids, M. Laurent boiled them with a slight excess of carbonate of soda, which dissolved the solid chlorophenisic acid, and left the oily chlorophenesic acid. The chlorophenisic acid is separated from soda by nitric acid, and obtained pure by distillation.

Chlorophenisic acid. This acid is white and solid, and has a peculiar smell, so tenacious that M. Laurent could not enter into company four days after he had touched it, without every person complaining of the disagreeable smell, though he had changed every part of his dress, and washed every part of his body with water. It is insoluble in water, though it communicates its smell to that liquid. It is exceedingly soluble in alcohol and ether. When water is added to a concentrated alcoholic solution of it, drops of oil separate, which slowly lose their alcohol and become solid. Water mixed with a little alcohol dissolves chlorophenisic acid, and the solution, on cooling, deposits the acid in long needles, seemingly oblique four-sided prisms. They melt, when heated, to 111°, and boil at about the temperature of 482°. The whole may be distilled over without decomposition. On cooling, it concretes into an acicular mass. When heated on platinum foil over a lamp, it burns with a yellow flame bordered with green, and gives out a great deal of smoke.

It is insoluble in sulphuric and muriatic acids, and does not appear to be acted on by these acids. Nitric acid gives it a brown colour, and, at a boiling temperature, decomposes it. A very volatile crystallizable substance is formed. Chlorine does not act upon it while cold. When heated it alters it but very slowly.

M. Laurent analyzed distilled chlorophenisic acid, and found it composed of

Carbon	35·61 or	12 atoms =	9	or per cent.	34·62
Hydrogen	1·90 or	4 atoms =	0·5	— —	1·92
Oxygen	11·74 or	3 atoms =	3·0	— —	11·53
Chlorine	50·75 or	3 atoms =	13·5	— —	51·93
	100·00		26		100·00

To determine the atomic weight of chlorophenisic acid, M. Laurent analyzed chlorophenisate of barytes, and found it composed of

Chlorophenisic acid .	72·05	or 24·48
Barytes . . .	27·95	or 9·5
	100·00	

According to this analysis, the atomic weight of chlorophenisic acid is 24·48. By the direct analysis, assuming the atoms as above stated, the atomic weight is 26, the difference is 1·52. M. Laurent considers the reason of this difference to be, that chlorophenisic acid, as analyzed by him, contained 1 atom water. If we subtract this atom, we have for the constitution of the acid

12 atoms carbon . .	= 9
3 atoms hydrogen . .	= 0·375
2 atoms oxygen . .	= 2·00
3 atoms chlorine . .	= 13·5
	24·775

This would reduce the atomic weight to 24·875.

The chlorophenisates are distinguished by the following characters:—

1. When heated on platinum foil they burn with a flame green round the edges, and giving out much smoke; at the same time they emit a smell characteristic of chlorophenisic acid.
2. When distilled they furnish chlorophenisic acid, and leave a chloride mixed with charcoal.
3. When nitric acid is dropt into the solution in water a copious and bulky precipitate falls easily, known by the characters given above.
4. The soluble chlorophenisates, when mixed with nitrate of silver, let fall a lively yellow precipitate, which acquires a green tinge by boiling.

The neutral chlorophenisate of ammonia gives, with corrosive sublimate, a white curdy precipitate; with nitrate of lead, a copious white precipitate; with alum, a gelatinous precipitate; with the persalts of iron, a reddish precipitate; and with the protosalts a white precipitate. It does not precipitate the salts of lime nor barytes.

The *chlorophenisates* of potash and soda are soluble; the latter crystallizes in silky needles.

The chlorophenisate of barytes is little soluble in water, and crystallizes by spontaneous evaporation in silky tufts. Its solution is decomposed by carbonic acid, which throws down a precipitate of

chlorophenisic acid. When we distil, a chloride of barium remains, and chlorophenisic acid passes over.

When neutral chlorophenisate of ammonia is evaporated, ammonia is disengaged, and an acid salt is deposited in fine short needles. This salt is very little soluble in cold water, but very soluble in water mixed with a little alcohol. When exposed to the sun on a funnel it partly sublimes, and attaches itself to the sides of the funnel in exceedingly light woolly flocks. When we distil it in a retort, ammonia, azotic gas, and chlorophenisate of ammonia are disengaged, together with both chlorophenisic and chlorophenesic acids. This salt was analyzed by M. Laurent, who obtained

Carbon	30·92 or	24 atoms =	18	or per cent.	31·92
Hydrogen	2·81 or	13 atoms =	1·625	— —	2·88
Azote	3·40 or	1 atom =	1·75	— —	3·10
Oxygen	15·77 or	8 atoms =	8·00	— —	14·19
Chlorine	47·10 or	6 atoms =	27·00	— —	47·91
	100		56·375		100·00

Now, 2 atoms chlorophenisic acid $C^{24}\ H^{6}\ O^{4}\ Chl^{6}$
1 atom ammonia . . $H^{3}\ Az$
4 atoms water . . . $H^{4}\ O^{4}$

$C^{24}\ H^{13} Az\ O^{8}\ Chl^{6}$

Making together the number of atoms found. Thus it appears that the salt analyzed is composed of

2 atoms chlorophenisic acid .	49·75
1 atom ammonia . . .	2·125
4 atoms water . . .	4·5
	56·375

Chlorophenesic acid. When this acid, separated from the chlorophenisic acid by the method above stated, is purified by distillation, it is an oily liquid, having a smell similar to that of the preceding acid. It may be distilled over without decomposition. It is insoluble in water; but exceedingly soluble in alcohol and ether. When acted on by boiling nitric acid, it forms a very volatile crystalline matter, propably the same as that formed by a like process from the chlorophenisic acid. When liquid ammonia is poured on the oily acid, the whole concretes into a crystalline matter. When the compound is exposed to the air, it gradually loses its ammonia, and becomes again an oily liquid; but solidifies anew when liquid ammonia is added. This salt is soluble in water. M. Laurent subjected this acid to analysis, and obtained the following result:—

Carbon	40·91 or	12 atoms =	9	or per cent.	41·62
Hydrogen	2·96 or	5 atoms =	0·625	— —	2·89
Oxygen	13·13 or	3 atoms =	3	— —	13·87
Chlorine	43·00 or	2 atoms =	9	— —	41·62
	100·00		21·625		100·00

These numbers do not correspond well with the result of his analysis. But the reason of this he supposes to be, that the acid, as he examined it, contained a mixture of chlorophenisic acid.

If we admit the presence of an atom of water, as in the chlorophenisic acid, then the true constitution of chlorophenesic acid will be

12 atoms carbon . . .	= 9
4 atoms hydrogen . . .	= 0·5
2 atoms oxygen . . .	= 2
2 atoms chlorine . . .	= 9
	20·5

So that its atomic weight is 20·5, and it differs from chlorophenisic acid by containing 1 atom more of hydrogen, and 1 less atom of chlorine. The excess of chlorine (more than 1 per cent.) was owing to the existence of chlorophenisic acid in the chlorophenesic acid analyzed; for when kept for some weeks it had deposited a small quantity of that acid.

Chlorophenesic acid will be converted into chlorophenisic acid, if we substitute an atom of chlorine for one of the atoms of hydrogen which the former acid contains.

SECTION X.—OF SANTONIN.

This substance, which possesses acid properties, though its affinity for bases does not seem very strong, was discovered about the same time by Köhler and Alms, in the seeds of the *artemisia sontonica*, or *southernwood*. Its properties were afterwards examined more in detail by Trommsdorf, junior.* He procured it in the following manner:—

Four parts of coarsely pounded seeds of santonicum were mixed with $1\frac{1}{2}$ parts of dry quicklime, and digested three times in succession with from 16 to 20 parts of spirits, of the specific gravity 0·94. These three solutions were mixed and distilled, till only about 14 parts remained. This last portion was allowed to cool, and then filtered, to separate the matter which had been deposited.

The filtered liquid contained a compound of lime and santonin. It was evaporated to half its original bulk, and, while still warm, mixed with acetic acid in excess, and left to cool. The santonin was gradually deposited in feathery crystals, mixed with a brown resinous body, the combination of which, with lime, existed also in the solution. The mother ley was evaporated to the consistence of a syrup, and then diluted with cold water. A precipitate, consisting partly of santonin crystals, remained undissolved. These two deposits of santonin were mixed, and treated with as small a quantity of cold alcohol as was sufficient to dissolve the resin, without dissolving more than could be avoided of the santonin. The santonin is now collected on a filter, and washed with cold alcohol, added by little and little, till it ceases to acquire colour. The remaining santonin is dissolved in from eight to ten times its weight of boiling

* Ann. der Pharmacie, xi. 190.

alcohol, of the specific gravity 0·844, mixed with a little ivory black, agitated, filtered, and left to cool. The santonin crystallizes in a state of purity. It must be carefully kept from the action of light.

The alcohol employed in washing the santonin, contains a portion of it in solution. Distil off the alcohol, dissolve the residue in warm caustic alkaline ley, and dilute the solution with 6 or 8 times its weight of cold water. Mix it with an excess of acetic acid. The resin precipitates; and the liquid, after filtration and some evaporation, deposits santonin, which must be dissolved in alcohol and crystallized.

Santonin, thus obtained, possesses the following properties:—It crystallizes in six-sided prisms, in long plates, or rectangular tables and feathery crystals. It is colourless, and destitute of smell and taste; but when long chewed an impression of bitterness is perceived. It refracts the light strongly, and when exposed to it for a few minutes, becomes yellow. In the dark it undergoes no change. Its specific gravity is 1·247 at 70°. When heated to about 276° it melts into a colourless liquid, which crystallizes on cooling, and loses no weight. If we raise the temperature a few degrees higher than 276°, it emits a white smoke, and may, with sufficient care, be sublimed in needles without alteration. If the temperature be raised still higher, the sublimate becomes yellow, and does not crystallize. In the open air it burns with flame, giving out smoke. It requires between 4 and 5000 times its weight of cold, and 250 times its weight of boiling water to dissolve it.

It requires 43 times its weight of alcohol of 0·848 at 59° to dissolve it; 12 times its weight at 122°; and only 2·7 times its weight at 176°. It requires 280 times its weight of spirits of specific gravity 0·928 to dissolve it at 59°, and 10 times its weight at 178°. It dissolves in 75 times its weight of cold, and 42 times its weight of boiling ether. It is soluble likewise in fixed and volatile oils. None of these solutions act upon vegetable colours; but the alcoholic solution has a very bitter taste. When in a state of fusion, it neither unites with sulphur nor phosphorus. Chlorine and iodine have little action on it; but if it be heated along with them it is destroyed.

Sulphuric acid dissolves santonin without altering its colour, and water throws it down again unaltered. If the solution be left to itself, it gradually assumes a yellow colour, then becomes blackish-brown, and water throws down a brown substance, which contains unaltered santonin mixed with it. If we boil it with sulphuric acid, and then dilute the solution with water, the same alteration is produced.

Nitric acid of 1·35 specific gravity dissolves santonin by the assistance of heat, and allows it to fall again in crystals when the solution cools. By long boiling in this acid, decomposition is produced, oxalic acid being formed, and a bitter tasted substance precipitable by water. Phosphoric and muriatic acids have no action while cold,

but at a boiling heat they dissolve santonin, and change it into a brown resinous-like substance. Acetic acid dissolves santonin cold; hot acetic acid dissolves it in greater quantity; but the excess crystallizes as the solution cools.

Santonin unites with the alkalies and salifiable bases, with a weak but evident affinity. Most of its compounds with the metallic oxides are, to a certain extent, soluble in water. The saturated solutions cannot be boiled; the bases separate and precipitate when they are insoluble, and when the liquid cools the santonin crystallizes.

Santonate of potash may be formed by boiling santonin in a concentrated potash ley. When the liquid acquires a certain degree of concentration, the salt separates in yellow oily drops, which, on cooling, constitute a soft, uncrystallizable matter, which is soluble in alcohol, and may be melted by heat. This salt is best obtained when santonin is dissolved in an excess of boiling hot carbonate of potash. The solution is to be evaporated to dryness, and the santonate obtained by digesting the residue in anhydrous alcohol. When the alcohol is evaporated, the santonate is obtained in a white or yellow indistinctly crystallized mass. It melts easily, is soluble in alcohol, and tastes and reacts as an alkali. If we dissolve it in water and boil the solution for a few minutes, the salt is decomposed, and the santonin is deposited in crystals when the solution cools. If santonin be treated with potash and weak alcohol, the liquid, during the solution, becomes carmine red, but this colour disappears as soon as the salt is formed.

It may be combined with the other bases, but not without the agency of alcohol.

Santonate of soda may be prepared in the same way as santonate of potash. It crystallizes in small colourless prisms, grouped together, and when exposed to the rays of the sun, acquires a yellow colour.

Santonate of ammonia exists only in solution. When we attempt to evaporate, the ammonia flies off, and leaves the santonin.

We obtain *santonate of lime* by boiling a mixture of santonin and quicklime in spirits. The solution is freed by carbonic acid of any excess of lime which it may contain. When filtered and left to spontaneous evaporation, the salt crystallizes in brilliant needles. If the evaporation be pushed too far, the whole mass congeals in the form of needles. This salt dissolves readily in water and in spirits, but with difficulty in alcohol.

Santonate of barytes may be prepared in the same way, and possesses analogous properties.

Santonate of magnesia has not yet been prepared in a pure state, but it seems to be soluble in water.

Santonate of alumina is obtained in the state of a white precipitate by double decomposition. It is decomposed by boiling, and dissolved in an excess of the alum solution.

Santonates of zinc, protoxide of iron, and *oxide of copper*, are soluble in a certain quantity of water, but when formed by double decom-

positions, they separate from the concentrated solution. The santonate of zinc is colourless, and crystallizes. The protosantonate of iron is white, finely divided, and speedily becomes yellow. The santonate of copper, in flocks and light-blue.

The *persantonate of iron* is isabella-yellow, and insoluble in water, but soluble in alcohol.

Santonate of lead is insoluble in cold water, but somewhat soluble in boiling water. It crystallizes in fine silky needles. It is soluble in alcohol, and crystallizes when a saturated boiling solution is left to cool. When boiled with an excess of acetate of lead, it is changed into a disalt, and the santonin is left behind.

Santonate of silver is a white precipitate, soluble both in water and in alcohol.

Santonate of black oxide of mercury is white, insoluble in water, but soluble in alcohol.

Santonate of red oxide of mercury is so soluble that it does not separate, except from a very concentrated solution. It is very soluble in alcohol.

A saturated boiling solution of santonin in water gives, with infusion of nutgalls, a yellow precipitate, soluble in alcohol.

The change of the colour of santonin from white to yellow, when exposed to the sun's rays, is remarkable. This change takes place *in vacuo*, and under water, alcohol, ether, oils, &c. When fused, santonin is exposed to the light of the sun, it splits in all directions. The violet end of the spectrum acts much more powerfully upon santonin than the red end. The common light of day acts slowly. After this change has taken place, the red colour, observable when santonin is acted on at once by potash and alcohol, does not appear. The colour becomes yellow, and this colour disappears when the alkali is saturated.

The yellow uncrystallized body, obtained by the sublimation of santonin, deserves attention. It is insoluble in water, but dissolves readily in alcohol, ether, and potash. With the uncombined alkalies it strikes an intensely red colour, and might be employed as an excellent re-agent for detecting their presence. It is the change of the santonin into this yellow substance by heat, that occasions the red colour, when heat is applied to an alkali and alcohol in contact with santonin.

Liebig has given us the result of an analysis of santonin, partly by himself, and partly by Ettling and Laubenheimer:—

Carbon	73·63 or 5 atoms	= 3·75	or per cent. 73·17
Hydrogen	7·21 or 3 atoms	= 0·375	— — 7·32
Oxygen	19·16 or 1 atom	= 1·00	— — 19·51
	100·00*	5·125	100·00

The atomic weight of santonin not being known, these numbers supply us only with the ratios of the atomic constituents. It is ob-

* Annalen der Pharmacie, xi. 207.

vious, from the phenomena, that this atomic weight is much higher than 5·125. Liebig supposes it to be 12 times as high. This would make santonin a compound of

60 atoms carbon . . .	= 45
36 atoms hydrogen . .	= 4·5
12 atoms oxygen . .	= 12
	61·5

This would make the atomic weight 61·5.

Liebig observed that the alcoholic solution of santonin reddens litmus. It is obvious that it possesses the characters of an oily acid.

SECTION XI.—OF SMILACIN.

I place this substance here, though its acid characters have not been accurately determined, on account of the great resemblance which it bears to santonin.

It is obtained from the root of the *smilax sarsaparilla*, or the *sarsaparilla* of apothecaries. This root was first examined by Pallota,* who extracted from it a peculiar substance, to which he gave the name of *pariglin*. It was afterwards examined by Folchi, and called by him *smilacin*. Thubeuf followed next, and gave it the name of *sasseparin*.† Batka‡ published a set of experiments on the root of the sarsaparilla, and drew as a conclusion from them, that the peculiar substance distinguished by the above names was an acid, to which he gave the name of *parillinic acid*.

Poggiale§ has examined the statements of his predecessors, and has come to the conclusion, that the *pariglin*, *smilacin*, *sasseparin*, and *parillinic acid* are all one and the same substance, under different names. To this substance, the properties of which he has eaxmined, he has given the name of *sasseparin;* but the term *smilacin*, applied to it by Folchi, is so much more agreeable to the ear, that there can be no hesitation in adopting it.

The best mode of procuring smilacin is the process of Thubeuf. It is as follows:—

Digest the root in warm alcohol. Distil off $\frac{7}{8}$ths of this tincture. Digest the residue for 24 hours with animal charcoal, and filter while the liquid is still hot. On cooling, the smilacin is deposited in crystals. By repeated solutions and crystallizations, it is obtained pure. If we evaporate the mother ley to dryness on the water-bath, and treat the dry residue with hot water, resin and fatty matter are left behind. The aqueous solution being evaporated to dryness, and the residue treated with alcohol, we may obtain more smilacin by evaporating the alcohol.

Smilacin thus obtained is a white powder, which, when dissolved in alcohol, and left to spontaneous evaporation, crystallizes in fine needles. They are white and tasteless while solid, but have a bitter

* Jour. de Pharmacie, x. 543. † Ibid. xviii. 734. ‡ Ibid. xx. 43.
§ Jour. de Ch. Medic. x. 577, or Jour. de Pharmacie, xx. 553.

taste when dissolved. They are heavier than water. They dissolve with difficulty in cold, but more easily in boiling water. They dissolve in alcohol whether hot or cold. Both the aqueous and alcoholic solutions froth like soap-suds when agitated. Smilacin is soluble in hot ether and in volatile oils, and somewhat soluble in fixed oils.

When heated it melts into a yellow liquid, is charred and destroyed, leaving a very brilliant charry matter behind. It is soluble in dilute acid and alkaline solutions, and is thrown down when the acids or alkalies are saturated. In these respects it is analogous to santonin. Sulphuric acid gives it a dark red colour, which changes to violet, and lastly to yellow. But water throws down the smilacin unaltered. By nitric acid it is very slowly converted into a yellow substance. When dissolved in muriatic acid, and the solution evaporated on the water-bath, the smilacin is deposited in beautiful crystals.

Smilacin was analyzed no fewer than 12 times by Poggiale,* and once by Henry. The mean of these analyses gives

Carbon	62·58 or 9 atoms	= 6·75	or per cent.	63·15
Hydrogen	8·86 or $7\frac{1}{2}$ atoms	= 0·9375	— —	8·77
Oxygen	28·66 or 3 atoms	= 3·00	— —	28·08
	100·00	10·6875		100

According to Poggiale, the crystals contain 8·56 per cent. of water. If this be one atom, then the atomic weight of smilacin will be 12. For

Water . . .	8·56 or 1·125
Smilacin . . .	91·44 or 12·01

It is evident from this, that the formula deduced from the analyses, is not correct. 1·3125 = 1 atom oxygen + $2\frac{1}{2}$ atoms hydrogen being wanting to make up the atomic weight 12.

SECTION XII.—OF ŒNANTHIC ACID.

This acid was discovered by Liebig and Pelouze, constituting one of the component parts of œnanthic ether to which wines owe their peculiar smell. If the oily liquid obtained in small quantity when wine is distilled, be agitated with carbonate of soda, the alkali is gradually saturated with œnanthic acid, provided the quantity of the oily liquid be sufficient. On adding sulphuric acid to the œnanthate of soda thus formed, the acid separates in a butyraceous state. It must be washed with hot water, and then dried, either by agitation with chloride of calcium, or *in vacuo* over sulphuric acid.†

Œnanthic acid thus obtained, at the temperature of 55°$\frac{3}{4}$, is snow-white, and has the consistence of butter. At a higher temperature it melts into a colourless oil, without taste or smell, which

* He analyzed three times successively, *sasseparin*, *pariglin*, *parillinic acid*, and *smilacin*, and found the composition of all the same.

† Ann. de Chim. et de Phys. lxiii. 118.

reddens litmus paper, and dissolves readily both in caustic alkalies and in their carbonates.

Like all the oily acids it forms two series of salts, the one set acid, the other neutral, which last have a strong alkaline reaction. When we neutralize a hot solution of œnanthic acid with potash till the liquid neither reacts as an acid nor alkali, and allow the liquid to cool, the whole concretes into a pasty mass composed of very small needles, having a silky lustre when dried. In this state the salt is a superœnanthate of potash.

If we dissolve œnanthic acid in hot solution of carbonate of soda, evaporate the solution to dryness, and digest the residue in alcohol, we dissolve a neutral œnanthate of soda, and carbonate of soda remains undissolved. The solution, on cooling, concretes into a gelatinous semitransparent mass.

If we mix cold œnanthic acid with a solution of acetate of lead, white flocks, constituting an insoluble salt, immediately appear. Acetate of copper produces a similar decomposition. These insoluble salts are supersalts. They dissolve readily in alcohol, and crystallize when a hot saturated alcoholic solution is allowed to cool.

The œnanthates are exceedingly easily decomposed, and it is difficult to obtain them in a definite state of composition. Very often they are mixtures of superœnanthates and œnanthates in various proportions. This makes it hardly possible to determine the atomic weight by analysis. The œnanthate of copper was found composed of

Œnanthic acid	.	74·03 or 14·25
Oxide of copper	.	25·97 or 5
		100

This would make the atomic weight of the acid 14·25.

Œnanthic acid, when first prepared, contains an atom of water; but when distilled it abandons its water and becomes anhydrous. In both states it was analyzed by Liebig and Pelouze. They found the hydrous acid composed of

Carbon	68·39 or 14 atoms	=	10·5	or per cent.	68·86
Hydrogen	11·73 or 14 atoms	=	1·75	— —	11·47
Oxygen	19·88 or 3 atoms	=	3	— —	19·67
	100		15·25		100

The anhydrous acid has a higher point of boiling than the hydrous. Its point of fusion is also higher. When liquid, it does not become solid till cooled down to 88°. Its constituents were found to be

Carbon	73·88 or 14 atoms carbon	=	10·5
Hydrogen	12·19 or 13 atoms hydrogen	=	1·625
Oxygen	13·93 or 2 atoms oxygen	=	2
	100·00		14·125

It is obvious to the eye that it contains an atom of water less than the hydrous acid.

The composition of œnanthic ether, which will be given in a subsequent part of this work, leaves no doubt that the atomic weight of this acid is 14·125, and that its constitution is C^{14} H^{13} O^{2}.

CHAPTER IV.

ACIDS CONTAINING AZOTE.

These acids (excluding a few belonging to the order of compound acids, and the acids from cyanogen,) are 8 in number. The following table exhibits their names and composition:—

1	Azulmic	C^{8} H^{4} Az^{4} O^{4}
2	Indigotic	C^{23} $H^{7\frac{1}{2}}$ $Az^{1\frac{1}{2}}$ O^{15}
3	Carbazotic	C^{15} Az^{3} O^{15}
4	Aspartic	C^{8} H^{5} Az O^{6}
5	Cholesteric	C^{13} H^{10} $Az^{\frac{1}{2}}$ O^{6}
6	Ambreic	C^{57} H^{47} Az^{4} O^{27}
7	Nitrosaccharic } Not analyzed.	
8	Nitroleucic }	

SECTION I.—OF AZULMIC ACID.

When an aqueous or alcoholic solution of cyanogen gas is left in a well stoppered phial, it undergoes spontaneous decomposition, and a dark-brown substance, almost black, precipitates. To this substance M. Pollydore Boullay has given the name of azulmic acid.*

It is insoluble in water whether cold or hot. It is equally insoluble in alcohol; but concentrated nitric acid dissolves it without the assistance of heat, and it assumes a beautiful aurora-red colour. Water renders this solution muddy; but the precipitate dissolves in alkaline bases and in ammonia. The solution has a very deep-brown colour, similar to that of ulmate of potash, only a good deal redder. The acids throw down from it a very light precipitate of a reddish-brown colour, which, when dry, is nearly destitute of lustre, and it has a good deal of resemblance to china ink.

The metallic salts throw down a brown precipitate, and completely deprive the solution of colour. When heat is applied, azulmic acid is converted into hydrocyanate of ammonia, which sublimes, and, if the heat be still farther raised, a gas is evolved, which burns with a blue flame, and has the odour of cyanogen: a quantity of charry matter remains in the retort.

Several interesting experiments on azulmic acid have been made in the course of the winter 1837–8, by M. Pelouze and Mr Richardson, in M. Pelouze's laboratory in Paris. They first analyzed the azulmate of silver and found it composed of

* Ann. de Chim. et de Phys. xlii. 281.

Azulmic acid . . .	17·57
Oxide of silver . . .	14·5
	32·07

Indicating 17·57 for the atomic weight of that acid. This salt being analyzed by means of oxide of copper, gave

Carbon	18·884 or 8 atoms	= 6	or per cent.	18·75
Hydrogen	1·833 or 4 atoms	= 0·5	— —	1·56*
Azote	21·868 or 4 atoms	= 7	— —	21·87
Oxygen	12·149 or 4 atoms	= 4	— —	12·50
Oxide of silver	45·266 or 1 atom	= 14·5	— —	45·32
	100·000	32		100

Hence the formula for azulmic acid is $C^8\ H^4\ Az^4\ O^4$, and its atomic weight 17·5.

When cyanogen undergoes spontaneous decomposition in water, it has been inferred by Pelouze and Richardson, from their experiments, that for every 11 atoms of it which undergo decomposition, 17 atoms of water are decomposed at the same time.

11 atoms of cyanogen are	$C^{22}\ Az^{11}$
17 atoms water are .	$H^{17}\ O^{17}$
Making together .	$C^{22}\ Az^{11}\ H^{17}\ O^{17}$
They are converted into	
1 atom urea . . .	$C^2\ Az^2\ H^4\ O^2$
3 atoms hydrocyanic acid	$C^6\ Az^3\ H^3$
4 atoms carbonic acid .	$C^4\ O^8$
1 atom ammonia . .	$Az\ H^3$
1 atom oxalate of ammonia	$C^2\ Az\ H^3\ O^3$
1 atom azulmic acid .	$C^8\ Az^4\ H^4\ O^4$
	$C^{22}\ Az^{11}\ H^{17}\ O^{17}$

These atomic numbers agree with the atomic weight of 11 atoms of cyanogen; but the supposition that 11 atoms cyanogen and 17 atoms water undergo mutual decomposition seems rather strained.

SECTION II.—OF INDIGOTIC ACID.

To the account of indigotic acid given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 153), I have the following addition to make:

This acid has been called nitranilic† by Berzelius. Besides the analysis of Buff, given in the *Chemistry of Inorganic Bodies*, there is another which he made at a later period, and which he considered as more exact. It is as follows:—

Carbon	49·575 or 15 atoms	= 11·25	
Azote	7·588 or 1 atom	= 1·75	
Oxygen	42·837 or 10 atoms	= 10	
	100·000‡		23·00

* Reckoning the hydrogen 1 atom less than given by the analysis.

† From *anil*, a species of the *Indigopera*. ‡ Ann. de Chim. et de Phys. xli. 176.

Buff found indigotate of barytes composed of

Indigotic acid . .	10 or 13·57
Barytes . . .	7 or 9·5
	17

This would make the atomic weight of the acid only 13·5, while the weight derived from indigotate of lead is 27·08, or just double.

But Dumas, who has analyzed this acid with great care, and in a state of great purity, has found hydrogen one of its constituents. According to him it is composed of

Carbon	48·09
Hydrogen	2·61
Azote	7·40
Oxygen	41·90
	100·00*

From this analysis the following formula may be deduced:

23 atoms carbon	= 17·25	or per cent.	48·17
$7\frac{1}{2}$ atoms hydrogen	= 0·9375	— —	2·61
$1\frac{1}{2}$ atom azote	= 2·625	— —	7·33
15 atoms oxygen	= 15	— —	41·89
	35·8125		100·00

So that it is merely indigo, containing five times as much oxygen as that pigment does.

SECTION III.—OF CARBAZOTIC ACID.

This acid has been described in the *Chemistry of Inorganic Bodies*, (vol. ii. p. 151).

It has been called *nitropicric*† by Berzelius.

Its composition, as determined by Liebig's analysis, is

Carbon	36·081 or 5 atoms	= 3·75
Azote	16·714 or 1 atom	= 1·75
Oxygen	47·205 or 5 atoms	= 5
	100·000	10·5

But as the atomic weight is above 30, we must multiply these numbers by 3. This gives us

15 atoms carbon . . .	= 11·25
3 atoms azote . . .	= 5·25
15 atoms oxygen . . .	= 15
	31·5

This gives us 31·5 for the atomic weight of carbazotic acid, which is very nearly the mean of the numbers derived from Liebig's analysis of the carbazotates of potash and barytes, as given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 152), that mean being 30·7.

* Jour. de Pharmacie, xx. 32. † From *nitro*, and πικρος, *bitter*.

Dumas has subjected this acid to a careful analysis, and considers its constituents to be

Carbon	31·3 or $12\frac{1}{2}$	atoms =	9·375	or per cent.	31·25
Hydrogen	1·3 or 3	atoms =	0·375	— —	1·25
Azote	17·7 or 3	atoms =	5·25	— —	17·5
Oxygen	49·7 or 15	atoms =	15	— —	50
	100·0*		30		100·0

SECTION IV.—OF ASPARTIC ACID.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 160), the discovery and character of this acid have been given. Since that time it has been shown that *asparagin*, a crystallized substance discovered in 1805, in the juice of *asparagus*, by Robiquet, and still more abundant in the *althæa officinalis*, is nothing else than *aspartate of ammonia*,† or rather *asparamide*. This curious discovery was made by MM. Boutron-Charlard and Pelouze.‡ These chemists obtained asparagin from the roots of the althœa by cutting them into small pieces, and macerating them twice successively in four times their weight of cold water, filtering the liquor through cloth, concentrating it sufficiently over the water-bath, and setting it aside for four or five days in a cold place. The asparagin was deposited in crystals. They procured aspartic acid by boiling an excess of barytes water with asparagin till all the ammonia was disengaged. The liquid was then filtered, and the barytes exactly saturated with sulphuric acid while the liquid was hot. On cooling, the aspartic acid almost wholly precipitates in small silky crystals.

Aspartic acid, when exposed to a heat of 248°, loses no weight. But Liebig has shown that it contains 2 atoms of water.§

Its atomic weight was determined by analyzing the aspartates of lead and silver.

Aspartate of lead, dried at 248°, was composed of

Aspartic acid . .	669 or 14·68
Oxide of lead . .	638 or 14

Aspartate of silver was composed of

Aspartic acid . .	430 or 14·5
Oxide of silver . .	430 or 14·5

According to these analyses, the atomic weight of aspartic acid appears to be 14·5.

Aspartic acid, in the state of crystals, was analyzed both by MM. Boutron-Charlard and Pelouze, and by M. Liebig. They obtained the following results:—

* Jour. de Pharmacie, xx. 32.

† *Agedoite* of liquorice root is the same as asparagin. See Jour. de Pharm. xiv. 177. The *althein* discovered by Bacon in the root of the *althea officinalis* (Ibid. xiii. 24) has been shown by M. Plisson to be the same as asparagin. (Ibid. p. 477.)

‡ Ann. de Chim. et de Phys. lii. 90. § Ibid. liii. 419.

	Boutron and Pelouze.	Liebig.*
Carbon	38·771	36·041
Hydrogen	5·500	5·355
Azote	11·266	10·386
Oxygen	44·463	48·021
	100·000	99·803

These numbers do not differ much from each other, except in the oxygen and carbon. Liebig's numbers gave an atom of oxygen more than the others. If we adopt his analysis as most exact, we obtain the composition of crystallized aspartic acid as follows:—

8 atoms carbon	= 6	or per cent.	36·10
7 atoms hydrogen	= 0·875	— —	5·27
1 atom azote	= 1·75	— —	10·51
8 atoms oxygen	= 8·00	— —	48·12
	16·625		100

But the atomic weight of the acid, instead of 16·625, was found only 14·5. This shows us that the crystals contain two atoms water, and that anhydrous aspartic acid is composed of

8 atoms carbon	= 6	or per cent.	41·74
5 atoms hydrogen	= 0·625	— —	4·34
1 atom azote	= 1·75	— —	12·18
6 atoms oxygen	= 6·00	— —	41·74
	14·375		100·00

SECTION V.—OF CHOLESTERIC ACID.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 143), an analysis of cholesterin by Chevreul has been given. It has been since subjected to a new analysis by M. Pelletier,† who found it composed of

Carbon	83·37 or $33\frac{1}{2}$	atoms =	25·125	or per cent.	83·40
Hydrogen	13·32 or 32	atoms =	4	— —	13·28
Oxygen	3·31 or 1	atom =	1	— —	3·32
	100·00		30·125		100

This is the very constitution of ambrein, so that, according to these analyses, ambrein and cholesterin are isomeric bodies.

Pelletier likewise subjected cholesteric acid to analysis, and obtained

Carbon	54·93
Hydrogen	7·01
Azote	4·71
Oxygen	33·35
	100·00

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 144), it is shown that the atomic weight of this acid, deduced from the best analyses

* Ann. de Chim et de Phys. liii. 419. † Ibid. li. 188.

at that time made, is 18. Pelletier considers his analysis of cholesterate of strontian as the most exact. He found it composed of

Cholesteric acid . .	100	or 17·57
Strontian . . .	36·98	or 6·5
	136·98	

According to this estimate, the atomic weight of cholesteric acid is 17·57. Now if it be composed of

13 atoms carbon	= 9·75	or per cent.	54·5
10 atoms hydrogen	= 1·25	— —	7·0
½ atom azote	= 0·875	— —	4·9
6 atoms oxygen	= 6·00	— —	33·6
	17·875		100·0

we obtain 17·875 for the atomic weight, and the resulting numbers agree very well with the analysis.

SECTION VI.—OF AMBREIC ACID.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 141), the history and characters of this acid have been given, together with the properties of ambrein, from which it was obtained by the action of nitric acid. M. Pelletier has since subjected both ambrein and ambreic acid to an ultimate analysis, by means of oxide of copper.*

Ambrein is composed of

Carbon	83·37 or 33½	atoms =	25·125	or per cent.	83·40
Hydrogen	13·32 or 32	atoms =	4	— —	13·28
Oxygen	3·31 or 1	atom =	1	— —	3·32
	100·00		30·125		100·00

M. Pelletier found the constituents of ambreic acid as follows:—

Carbon	51·942 or 57	atoms =	42·75	or per cent.	51·74
Hydrogen	7·137 or 47	atoms =	5·875	— —	7·11
Azote	8·505 or 4	atoms =	7·00	— —	8·47
Oxygen	32·416 or 27	atoms =	27·00	— —	32·68
	100·000		82·625		100·00

It is needless to speculate upon the composition of ambreic acid till its atomic weight be determined. But it would not be surprising if it were nothing else than a combination of an integrant particle of ambrein, deprived of a certain quantity of carbon and hydrogen, with two atoms of nitric acid.

2 atoms ambrein are	C^{67} H^{64} O^{2}
1 atom ambreic acid	C^{57} H^{47} O^{27} Az^{4}
Abstracted . . .	C^{10} H^{7}
Added	O^{26} Az^{4}

The oxygen in this quantity exceeds that in nitric acid by about ⅕th part. But the real quantity of oxygen in ambreic acid is less

* Ann. de Chim. et de Phys. li. 188.

than 27 atoms; and if ambrein contain no oxygen, the discrepancy would be diminished somewhat.

I have no addition to make to the account of the *nitrosaccharic* and *nitroleneic* acids, given in the *Chemistry of Inorganic Bodies* (vol. ii. pp. 162 and 164).

CHAPTER V.

ACIDS IMPERFECTLY EXAMINED.

These acids, 23 in number, have not yet been subjected to a chemical examination. This puts it out of our power to arrange them, and makes it necessary to put them in an order by themselves. This order will, of course, disappear when the necessary chemical examination of the acids arranged under it has taken place.

SECTION I.—OF PECTIC ACID.

I have nothing to add to the account of this acid, given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 120). But there is a substance in many of our acid fruits, as currants and gooseberries, which gelatinizes, and which, on that account, has been long familiar to most persons. This substance has a very intimate connection with pectic acid, being instantly converted into that acid by the smallest quantity of a fixed alkali. This substance has been distinguished by Braconnot, to whom we are indebted for examining it, by the name of *pectin*. I shall here state the most important of the facts which he has ascertained.*

Vauquelin, who found pectin in the tamarind, considered it as the same with pectic acid. John considered it as *bassorin*. And Guibourt, who thought it was a substance formed by the fermentation of currant juice, gave it the name of *grossulin*.

It may be obtained from all fruits by means of alcohol. If we digest the fruit in alcohol, and leave the solution for a couple of days to spontaneous evaporation, the pectin is deposited in a gelatinous coagulum. We have only to subject it to gradual pressure, and to wash it with weak alcohol, to obtain it in a state of purity. When dried, it is in translucent membranes, like isinglass.

Simonin has given the following simple process for obtaining pectin:—

Mix together the clear expressed juice of currants, with the equally clear juice of sour cherries. Pectin falls down. Decant off the liquid, and wash the pectin with water, as long as the liquid abstracts any colour.†

When dry pectin is plunged into about 100 times its weight of water, it swells up very much, and at last dissolves, forming a gelatinous mass like starch, but not rendered blue by iodine.

* See Ann. de Chim. et de Phys. xlvii. 266 and l. 381.

† Jour. der Pharmacie, xx. 467.

Boiling water has less action than cold water upon dry pectin. It dissolves also to a certain extent in dilute and boiling-hot alcohol. But the solution cannot be used as a paste, like a solution of gum or starch; nor has it the property of reddening litmus paper.

The least trace of a fixed alkali instantly converts it into pectic acid. The carbonate of potash has the property also of converting it into pectic acid. But neither carbonate of soda, nor concentrated ammonia possesses that property.

If we add an excess of potash or soda to the solution of pectin, the whole of it precipitates in the state of subpectate of the alkali.

Lime water converts pectin, at least partially, into pectic acid.

It is precipitated in gelatinous masses, soluble in dilute nitric acid by the soluble salts of barytes and strontian, the acetate of lead, the nitrate of copper, the nitrates of mercury, the sulphate of nickel, and the chloride of cobalt.

It is not altered by the infusion of nutgalls.

When distilled it does not melt, but gives off an empyreumatic oil and an acid product, in which M. Braconnot could not detect the presence of ammonia. There remains in the retort a very bulky charcoal, which, after incineration, leaves a yellow ash, consisting of carbonate of lime, sulphate of lime, phosphate of lime, and peroxide of iron.

When pectin is treated with nitric acid, it furnishes mucic and oxalic acids, and a slight trace of a bitter yellow matter.

Muriatic acid, heated with pectin, assumes a fine red colour, and red flocks are separated, which are insoluble in ammonia.

Such are the properties of pectin, as they have been determined by Braconnot. He found pectin also in the bark of all the trees which he examined. As neither pectic acid nor pectin have been subjected to analysis, we do not know the relation in which they stand to each other. One of the most striking differences between them is the action of cold water. Dry pectin, when put into cold water, swells up very much, and gradually dissolves, while pectic acid, under the same circumstances, is scarcely altered.

We still want a more minute examination of pectic acid and pectin; and, above all, a chemical analysis of each, to enable us to understand the relation in which they stand to each other.

SECTION II.—OF CRENIC ACID.

This acid was discovered by Berzelius, in the year 1832, in the water of Porla well, near Örebro, in Sweden. He had examined this water in 1807, and published the results of his analysis in the first volume of the *Afhandlingar* (p. 145). The crenic acid in that analysis was distinguished by the name of *extractive matter*. He recommenced his examination of this water again, and published the result in the *Memoirs of the Stockholm Academy* for 1833.*

* Kong. Vet. Acad. Handl. 1833, p. 18; and Poggendorf's Annalen, xxix. 1, and 238.

Porla water, though it proceeds from a strong spring, yet is so much charged with crenic acid,* that it has a yellow colour and a disagreeable taste. When left exposed to the air, the water lets fall an ochrey sediment, consisting chiefly of crenated peroxide of iron. Berzelius found the constituents in 100,000 parts of this water to be,

Water		99970·5942
Chloride of potassium	0·3398	
Chloride of sodium	0·7937	
Crenate of soda	0·6413	
Crenate and carbonate of ammonia	0·8608	
Bicarbonate of lime	9·0578	
Bicarbonate of magnesia	1·9103	
Bicarbonate of manganese	0·0307	
Bicarbonate of iron	6·6109	
Phosphate of alumina	0·0110	
Silica	3·8960	
Crenic acid	5·2535	
	29·4058	

It was from the ochrey deposits that Berzelius obtained the new acid, in quantity sufficient for examination. It was composed of

Crenated peroxide of iron	90·54
Carbonate of lime	3·54
Phosphate of alumina	0·38
Silica	5·54
	100·00

This ochre was boiled in caustic potash, which produced a brown solution, from which an ochrey matter fell when it was allowed to stand for some time. The ochre must be boiled with the caustic potash till the oxide of iron, instead of forming a fine powder, which passes through the filter, assumes the flocky appearance of the hydrated peroxide. The liquid, which has now a deep brown colour, is to be filtered, and acetic acid added in slight excess. Acetate of copper is now dropt into the liquid, as long as a brown-coloured precipitate falls. Should the precipitate be white, some more acetic acid must be added. This brown precipitate is the apocrenate of copper. The liquid thus freed from apocrenic acid is to be filtered, and saturated with carbonate of ammonia in slight excess. Add now acetate of copper, as long as a greenish-white precipitate continues to fall. The quantity of this precipitate, which is crenate of copper, is materially augmented by keeping the liquid for some time between the temperatures of 140° and 176°. Collect this crenate on a filter, and wash it. Mix it with water (taking care not to employ too much), and pass through it a current of sulphuretted hydrogen. Filter and evaporate the liquid to dryness *in vacuo*, over sulphuric acid.

* Named from κρηνη, *a fountain*.

Crenic acid thus obtained is yellowish-brown. If we dissolve it in absolute alcohol, a little crenate of lime usually remains undissolved. If the alcoholic solution be now evaporated to dryness *in vacuo*, the crenic acid remains still mixed with a little apocrenate of lime. To separate this salt, dissolve the acid in water, and add, drop by drop, to the liquid acetate of lead, as long as a brownish precipitate falls; filter, add diacetate of lead, and decompose the precipitate by sulphuretted hydrogen. The filtered liquid has now a yellow colour, and when evaporated *in vacuo*, leaves crenic acid in a state of purity.

Crenic acid thus obtained has a yellow colour, and is quite transparent. It seems to have no tendency whatever to crystallize. It has no smell. Its taste is sharp; at first acid, and afterwards astringent. When in solution, the astringent taste only can be observed. When the solution of this acid is exposed to the air, it assumes a brown colour, and apocrenic acid is formed.

In water and alcohol it is excessively soluble. Its salts resemble extracts, and are insoluble in absolute alcohol, but become more and more soluble the more water we add. When these salts are exposed to the air they become rapidly brown, and apocrenates are formed, which are easily separated by means of gelatinous alumina.

Crenic acid dissolves in cold nitric acid without any alteration. When heat is applied nitrous gas is disengaged, and nitric acid may be distilled over. By evaporation a yellow mass is obtained, having an intensely bitter taste. When an alkali is added, a combination takes place, and a crenate is formed.

When silica is separated from a solution of crenic acid, it contains a quantity of crenic acid, which may be separated by an alkali, but not completely; for, when the silica is heated, it gives out an animal smell, and becomes black.

When crenic acid is distilled, it affords an acid liquor, and a brownish-yellow oil. When potash is added, ammonia is disengaged; showing that crenic acid contains azote as a constituent.

To determine the atomic weight of this acid, Berzelius precipitated a solution of acetate of lead by pure crenic acid. The precipitate was white by reflected, and yellow by transmitted light. It was washed, and dried *in vacuo*, at a temperature of 212°. It weighed 0·59 gramme. Being decomposed by sulphuric acid 0·4165 gramme of sulphate of lead was obtained. Being ignited in a platinum crucible, it gave out smoke, and the weight was reduced to 0·41 gramme. It was now no longer altered by nitric acid. The matter thus driven off by heat, arose from a little apocrenate of lead, which had been mixed with the sulphate of lead.

Now, it will be shown in the next section, that the atomic weight of apocrenic acid is 16·75. Hence the oxide of lead which was combined with it in the sulphate, must have been 0·0054. And this quantity must have been united with 0·0064 of apocrenic acid, making together 0·0118. This quantity must be subtracted from

the 0·59 gramme of crenate of lead analyzed, because it was foreign matter, leaving 0·5782 gramme for the crenate of lead actually analyzed. Now, this gave 0·4046 sulphate of lead—·0054 oxide of lead with which it was mixed. This amounts to 0·3992 gramme, equivalent to 0·2980 oxide of lead.* So that the crenate of lead is a compound of

Crenic acid . .	28·02 or 13·498
Oxide of lead .	29·80 or 14
	57·82

We see, from this analysis, that the atomic weight of crenic acid is 13·5.

To verify this analysis, Berzelius saturated, as completely as possible, hydrate of lime with crenic acid, filtered the solution, and evaporated *in vacuo*. The salt constituted a dark yellow, hard translucent mass. To free it from any excess of crenic acid or acetate that might be present, it was digested two several times with alcohol, and then dried *in vacuo*, at the temperature of 212°. 0·261 parts of this salt gave 0·1305 anhydrous sulphate of lime = 0·0537 lime. Hence the crenate of lime is composed of

Crenic acid . .	20·73 or 13·51
Lime . . .	5·37 or 3·5
	26·10

These two analyses do great credit to the accuracy of Berzelius, and leave no doubt whatever that the atomic weight of crenic acid is 13·5.

The salts formed by combining this acid with the bases, are called crenates. They all resemble extracts in appearance, and are incapable of crystallizing. The following are those which have been examined by Berzelius :—

1. *Crenates of potash and soda.* These salts form yellow extractive-looking substances, which are hard and crack, and are easily detached from the glass. They are neutral, have hardly any taste, but when kept in the mouth an alkaline flavour is at last perceptible. They are insoluble in absolute alcohol; but are pretty soluble in alcohol of the specific gravity 0·86, and they are the more soluble the weaker the alcohol is. When heated, they swell up, give out a smoke having the smell of tobacco, and leave a porous coal, mixed with an alkaline carbonate.

2. *Crenate of ammonia.* This salt becomes acid when we attempt to concentrate it, and leaves a brown extractive-looking matter, which reddens litmus paper. In this state it still contains much ammonia, which may be separated by potash or lime.

3. *Crenate of barytes.* This salt is of such difficult solubility, that it may be obtained by double decomposition in the state of yellow flocks. But it may be dissolved in a sufficient quantity of water, leaving a resinous-looking varnish on the vessel.

* Berzelius, by not attending to these corrections, has not done justice to his own analysis, which almost coincides with that of *crenate of lime*.

4. *Crenate of lime.* This salt is more soluble than the preceding, but may be obtained also by double decomposition. When crenate of potash is added to chloride of calcium, crenate of lime precipitates in pale yellow flocks; but when we add chloride of calcium to crenate of potash, the liquid remains clear. When dissolved, it leaves a yellow translucent varnish, which is often mixed with a white earthy matter.

Crenate of lime is completely soluble in water. When the neutral salt is mixed with an excess of acid, evaporated, and then the excess of acid removed by alcohol, there remains a light yellow extractive-looking and easily soluble salt. We obtain a subsalt when the neutral salt is precipitated by lime water. It falls in light yellow flocks. We obtain the same salt when crenate of potash is mixed with hydrate of lime. Caustic potash in that case remains in solution in the liquid.

5. *Crenate of magnesia.* It is easily soluble in water, and resembles the alkaline crenates. It forms also a supersalt, which is slightly soluble in absolute alcohol.

6. *Crenate of alumina.* When a solution of crenic acid is mixed with moist hydrate of alumina, a neutral crenate of alumina is formed, which is yellow, and insoluble in water: but it dissolves in that liquid if we add an excess of acid. When the supersalt is evaporated by a gentle heat, there remains a yellowish translucent varnish, again soluble in water. When a solution of this salt is mixed with caustic ammonia, no precipitate falls, and when we evaporate to dryness we obtain a double salt, which is completely soluble in water. When this salt is burnt, snow-white alumina remains. Neutral crenate of alumina, when treated with ammonia, is partially decomposed. The double salt is formed, and subcrenate of alumina remains undissolved.

7. *Crenate of iron.* It is soluble in water. It may be obtained directly from the ochrey deposit from the water, by mixing it with water, and passing a current of sulphuretted hydrogen through the mixture. The iron is brought into the state of protoxide, which, united to the crenic acid, remains in solution. When evaporated *in vacuo*, it leaves a residue similar to that from the preceding salts. But a portion of the iron is apt to be peroxydized during the evaporation. Crenic acid dissolves metallic iron with great difficulty, and so as only to form with it a supersalt. The action was carried on in a cylindrical vessel, covered with a layer of olive oil, and continued for 24 hours. The olive oil became reddish-yellow, probably from having dissolved a portion of the iron salt, which would be peroxydized by exposure to the air. The colour of the liquid was not altered. It reddened litmus paper, and tasted as a salt of protoxide of iron. When exposed to the air, brown streaks appeared in it, but vanished on agitating the liquid; but by degrees it became all brown and muddy, and when evaporated to dryness, left a crenated peroxide of iron, no longer soluble in water, mixed with crenic acid.

8. *Crenated peroxide of iron.* Obtained when crenic acid is mixed with a neutral sulphated peroxide or chloride of iron. A light reddish-grey precipitate falls. When washed and dried it is earthy, and of dirty-white colour; but when moistened, becomes reddish-grey. It dissolves completely in ammonia. When the solution is evaporated, it leaves a reddish-yellow matter, from which water dissolves a double salt, leaving behind a subcrenated peroxide of iron, resembling in appearance hydrated peroxide of iron.

The percrenate of iron is precipitated by the fixed alkalies, both caustic and carbonated, and is not again dissolved by an excess of the alkali.

9. *Crenate of manganese.* It forms a soft pale-yellow insoluble powder. With an excess of acid, a salt is formed, which is soluble in water.

10. *Crenate of lead.* This salt is best obtained by adding crenic acid in small quantities at a time, to a weak solution of acetate of lead, as long as the precipitate continues to have a brown or yellow colour. The precipitate is to be well washed with cold water, and better still with alcohol, and dried *in vacuo*, over sulphuric acid. The salt is a light-grey powder, passing into yellow. It is very slightly soluble in water. It is also soluble in acetic acid, and somewhat in crenic acid. Hence acetate of lead is dropt into crenic acid, and the precipitate is again redissolved. When the solution is evaporated, a granular grey powder is deposited, which does not crystallize, and when stirred, is converted into flocks. This constitutes the neutral salt. The supersalt dries into a gummy mass. Subcrenate of lead is obtained by mixing subacetate of lead with crenic acid. It falls quite white. When dried *in vacuo* it acquires a slight shade of yellow. A solution of chloride of lead is not precipitated by *crenic* acid; but it is by crenate of potash.

11. *Crenate of copper.* This salt is precipitated from the acetate, but not from the sulphate of copper, by crenic acid. But crenate of potash occasions a precipitate in sulphate of copper. The precipitate appears at first to be dirty-white, but after it has been collected in the bottom of the vessel, it is light-grey, with a strong tint of green, or yellowish-green. It retains this colour when dry; but it is somewhat lighter in the shade. It is very slightly soluble in water, but dissolves readily in acetic acid, or an excess of crenic acid. It cannot be completely precipitated, unless the solution be heated to 122°. When its solution in acetic acid is evaporated, we obtain much of the red compound which appears when sugar is employed to produce acetate of copper.

A supercrenate is formed by adding crenic acid to the neutral solution. It dries into a gummy mass, insoluble in alcohol, soluble in water, and having a very disagreeable metallic taste. When saturated with an alkali, it gives a double salt, to which formation the crenate of copper has as much inclination as other copper salts. It dries into an extractive-like mass, having a metallic taste. It

is this tendency to form double salts that occasions the difficulty of precipitating crenate of copper.

Crenic acid forms also a subsalt with oxide of copper. It is obtained when the solution, which is mixed with acetate of copper, contains a determinate excess of base. It is a slimy greyish-green substance, darker than the neutral salt, and insoluble in water.

12. *Crenated suboxide of mercury.* It forms a flocky yellow precipitate, which appears when a solution of nitrated suboxide of mercury is dropt into crenic acid, or a solution of a crenate. A solution of corrosive sublimate occasions no precipitate in crenic acid, or a soluble crenate. Hence it would appear that the crenate of mercury is a soluble salt.

13. *Crenate of silver.* Crenic acid, when dropt into a solution of nitrate of silver, gives at first no, or only a trifling precipitate. But by degrees a greyish-white deposit takes place, which after some hours assumes a fine but dark purple colour. It does not blacken. When treated with nitric acid it becomes colourless. It is soluble in ammonia without residue, and the solution has a yellowish tint. If we mix a solution of crenate of potash with nitrate of silver, in such proportion that only a portion of the salt is decomposed, it remains clear, owing to the formation of a soluble double salt. The solution after some days becomes purple red. When the solution in which crenate of silver has precipitated is heated to 176°, the precipitate becomes brownish-yellow; not from the formation of apocrenate of silver, but from the appearance of a silver salt of quite another nature, which has not yet been sufficiently examined.

SECTION III.—OF APOCRENIC ACID.

This acid was obtained by digesting the ochre from Porla well with potash, to extract the crenic acid, and then precipitating the acid by means of acetate of copper. The apocrenate of copper falls.* It is to be washed in cold water, which assumes a yellowish colour, while the precipitate, which is a supersalt, is to be dissolved in pure water, as it is insoluble in the saline solution. This precipitate while still moist is agitated in a little water, and decomposed by sulphuretted hydrogen. It is very difficult to separate the sulphuret of copper from the solution. The best way is to evaporate and wash the residue with absolute alcohol, which dissolves the apocrenic acid, mixed with a small quantity of saline matter.

Another portion of the apocrenic acid remains on the filter, being little soluble in water. A solution of acetate of potash removes it, and passes with it in solution through the filter. After evaporating the solution, we separate the acetate of potash by alcohol of 0·86, in which apocrenic acid is not soluble. The apocrenate of potash may now be decomposed by muriatic acid.

Apocrenic acid thus obtained is brown, and resembles a vegetable extract. Its taste is purely astringent. It is only slightly soluble

* Poggendorf's Annalen, xxix. 252.

in water, but dissolves readily in a solution of crenic acid. It is more soluble in absolute alcohol than in water, though alcohol does not act upon it immediately. It is almost entirely precipitated from its solution in water by sal ammoniac, which throws it down in dark brown flocks, soluble anew in a large quantity of water. Its combinations with the alkalies are perfectly neutral. They have a blackish-brown colour, resemble an extract, and are insoluble in alcohol. It disengages acetic acid from its combinations. It is soluble in a solution of acetate of potash, which acquires the property of reddening litmus paper.

To determine the atomic weight of apocrenic acid, Berzelius decomposed apocrenate of lead, dried *in vacuo*, at the temperature of 212°. 0·4365 gramme gave 0·268 gramme of sulphate of lead. Now 268 : 436·5 : : 19 (an atom of sulphate of lead) : 30·57 (an atom of apocrenate of lead). Each of these containing 14 of oxide of lead, it is obvious that the atom of apocrenic acid must be 16·57. Berzelius also analyzed apocrenate of barytes. He does not give us the numbers, but merely states that the result gave the atomic weight of apocrenic acid, 16·422. Now the mean of these two numbers giving almost exactly 16·5, we can have no hesitation in adopting that number as the true atomic weight of this acid.

The apocrenates have been but imperfectly examined; owing, doubtless, to the small quantity of this acid which Berzelius had at his disposal.

1. *Apocrenates of potash and soda.* These salts are best obtained by dissolving apocrenic acid in acetate of potash or soda, evaporating the solution to dryness, and removing the alkaline acetate by alcohol. These salts dry into a black friable mass, full of cracks, which dissolves in water, giving the liquid a dark brown colour. The concentrated solution is somewhat mucilaginous. These salts are precipitated from their aqueous solution by alcohol.

2. *Apocrenate of ammonia.* The solution of this salt becomes acid when evaporated. 100 parts of apocrenic acid, dried *in vacuo*, at 212°, when saturated with ammonia and dried on the water-bath, gave 113·22 parts. It would follow from this (if no water be present) that the salt is composed of

Apocrenic acid . .	100	or 16·5
Ammonia . . .	13·22	or 0·82

Now 0·82 approaches 0·708, which is the third part of an atom of ammonia. It would appear from this that the salt formed was a tersalt, composed of

3 atoms apocrenic acid . .	49·5
1 atom ammonia . . .	2·125
	51·625

3. *Apocrenates of the alkaline earths.* These salts are dark brown precipitates, which, when washed, dissolve with a yellow colour. When the solution is evaporated, a brown matter full of cracks remains, which is again soluble in water. When there is an

excess of base, these salts are quite insoluble. An alkaline apocrenate can be rendered caustic by the addition of hydrate of lime.

4. *Apocrenate of alumina.* Apocrenic acid has a strong affinity for alumina. When it is digested with an excess of hydrate of alumina, the apocrenic acid is precipitated in combination with the alumina. When the alumina is not in excess, apocrenate of alumina is found in the solutions. When apocrenate of potash is digested with hydrate of alumina, the liquid becomes colourless, and a mere trace of apocrenic acid remains in the solution. The precipitate is dark brown, and contains both potash and alumina. When digested in ammonia, nothing is dissolved, or only a little crenate of alumina. After evaporating the ammoniacal liquid, a brown mass remains, from which water dissolves a supersalt, composed of crenic acid, alumina, and ammonia, and apocrenate of alumina remains undissolved.

Superapocrenate of ammonia dissolves a portion of hydrated alumina. But when the acid becomes saturated, the whole apocrenate of alumina falls down.

5. *Apocrenate of iron.* This salt is soluble in water, but when exposed to the air, it passes to the state of a subapocrenated peroxide. We obtain the subapocrenate of iron when apocrenate of potash, mixed with a little caustic ammonia, is mixed with a salt of protoxide of iron. It falls in black flocks, which become brown in the air, quite similar in colour to the ochre from the Porla well.

6. *Apocrenated peroxide of iron.* It is a black flocky precipitate, obtained by dropping apocrenic acid, or an apocrenate, into a neutral solution of sulphated peroxide of iron. It dissolves with a black colour in caustic ammonia. After evaporating the solution to dryness, there remains a black matter like an extract, from which water dissolves a neutral double salt, and leaves behind a subsalt of peroxide of iron. Caustic potash, dissolves apocrenated peroxide of iron, but a precipitate almost immediately falls. It consists of subapocrenated peroxide of iron, while apocrenate of potash remains in solution. Yet the solution still contains iron.

7. *Apocrenate of copper.* When obtained by precipitating acetate of copper, it is a supersalt, having a brown colour, and a mucilaginous consistence. Water dissolves a small quantity of it, and assumes a dark yellow colour. The solution has a metallic taste, and when evaporated, leaves a blackish-brown residue, again soluble in water. When the yellow solution is mixed with a small quantity of alkali, we obtain a precipitate similar in appearance, which is a neutral apocrenate of copper. With ammonia and soda it forms double salts.

Such are the characters of the crenic and apocrenic acids, so far as they have been ascertained. Berzelius is of opinion that they occur frequently in waters, and that the substances so often described by chemists, as existing in mineral waters, and which they have distinguished by the name of *extractive*, in reality consists of these acids. He thinks too that they exist abundantly in bog *iron ore*.

SECTION IV.—OF PUTEANIC ACID.

This acid was discovered, in 1835, by M. Haenlé, apothecary at Lahr, in the ochre which deposits abundantly in the wells of that neighbourhood. He obtained it in the following manner:—

The ochre was boiled in distilled water, in which one-twelfth of its weight of caustic potash had been previously dissolved. The filtered decoction was saturated with acetic acid, added slightly in excess, which disengaged carbonic acid. The puteanic acid was precipitated from this solution by acetate of lead, added as long as a precipitate of an uniform colour appeared. The precipitate was washed, and the lead disengaged from it by sulphuretted hydrogen. The filtered residue was evaporated to dryness *in vacuo* over sulphuric acid. Puteanic acid, obtained in this way, possesses the following properties:—

It is a resinous-looking body, transparent when in thin crusts, having a strong lustre, and a brown colour. It has no smell. Its taste is acid, sharp, and slightly astringent. It is quite insoluble in absolute alcohol, but dissolves readily in water, and the solution reddens litmus paper.

Nitrate of silver throws down a yellowish-brown precipitate, soluble in ammonia.

Acetate and subacetate of lead, throw down a yellowish-white, while acetate of copper throws down a whitish-yellow precipitate.

The protoxide of iron is soluble in a concentrated solution of this acid; but the peroxide of iron only dissolves when we add ammonia.

When puteanic acid is distilled, it evolves substances containing azote. When we add potash and distil, ammonia is disengaged.

When we saturate it with ammonia and evaporate, the greatest part of the alkali is disengaged, and the liquor becomes acid.

Puteanic acid is distinguished from crenic: 1. By a deeper colour. 2. By the whitish-yellow precipitate with acetate of copper, while crenic acid gives a greenish-white. 3. By its insolubility in absolute alcohol. 4. By the nitrate of silver, which, with puteanic acid, gives a brownish-yellow precipitate, which remains unaltered, while the precipitate, with crenic acid, soon changes into a reddish-purple.

It is distinguished from apocrenic acid: 1. By its sharp acid taste, while that of apocrenic acid is purely astringent. 2. By its solubility in water. The apocrenic acid is very little soluble in that liquid. 3. By its insolubility in absolute alcohol—apocrenic acid being more soluble in absolute alcohol than in water. 4. By its aqueous solution not being precipitated by sal ammoniac, while that of apocrenic acid is precipitated by that salt.*

SECTION V.—OF PALMIC ACID.

An account of this acid will be given in a subsequent part of this volume, while treating of castor oil.

* Jour. de Pharmacie, xxi. 310.

SECTION VI.—OF GUMMIC ACID.

This acid was discovered by M. Simonin, about the year 1830, and an account of it published by him in 1832.* His results were speedily confirmed by M. Guerin-Varry.†

Four ounces of gum senegal were dissolved in 61 cubic inches, or rather less than three wine pints of water, and a current of chlorine gas was passed through the solution for 48 hours. The liquid, which now contained a great deal of muriatic acid, was mixed with an excess of lime, when it emitted a smell of apples. The precipitate was well washed with water, and then decomposed by dilute sulphuric acid. Alcohol was added to the liquid, to throw down the whole sulphate of lime. It was then filtered, and evaporated to dryness.

What remains is a yellowish solid body, not the least crystalline, and reddening litmus paper. It scarcely attracts moisture from the atmosphere. It has the consistence of soft wax. When incinerated it leaves a little lime. It is very soluble in alcohol of 0·817, and also in spirits.

The aqueous solution of this acid is precipitated in a fine powder by acetate of lead, in scanty flocks by nitrate of silver, and in bulky flocks by lime and barytes water. These last precipitates are soluble in nitric acid.

With the salifiable bases it forms salts, which do not crystallize. When saturated with carbonate of lime it gives a very soluble salt, according to Simonin, which, when dried, resembles gum, does not attract moisture from the atmosphere, and whose solution is decomposed by sulphuric acid, which separates the lime.

Such are the properties of this acid hitherto ascertained. A more complete investigation would be necessary to determine whether it be a new acid, or a modification of malic acid, to which it bears some resemblance.

SECTION VII.—OF IGASURIC OR STRYCHNIC ACID.

This acid was discovered by Pelletier and Caventou, in the *strychnos nux vomica*, *strychnos Ignatii*, and the *strychnos colubrina*, the same which yield *strichnina*.

It may be extracted by the following process:—Rasp *nux vomica*, or *St Ignatius' bean*, and treat it first with ether, and then with alcohol. Evaporate the alcoholic solution, mix it with water, filter and digest the liquid with calcined magnesia, which throws down the strychnina, and form with the igasuric acid a salt, insoluble in cold water. The precipitated matter is first washed with cold water, and then boiled in alcohol, till the whole strychnina is dissolved. The residual matter is now boiled in a great quantity of water, which dissolves the igasurate of magnesia. This solution is now mixed with acetate of lead. Igasurate of lead precipitates,

* Ann. de Chim. et de Phys. l. 319. † Ibid. li. 222.

which is washed, and decomposed by a current of sulphuretted hydrogen gas. The filtered liquor, freed from sulphuretted hydrogen, is an aqueous solution of igasuric acid.

When sufficiently concentrated, it constitutes a brown syrup, from which the igasuric acid is gradually deposited in crystalline grains. Its taste is acid, and rough. It dissolves readily in water and in alcohol, and forms with the alkalies, salts which are very soluble in water and alcohol. With barytes it forms a salt very soluble in water. When the solution is evaporated, the salt is gradually deposited in spongy vegetations. The salts of iron, mercury, and silver, are neither precipitated nor altered by the igasurate of ammonia. The salts of copper are coloured green by this salt, and a light green precipitate gradually falls, little soluble in water, which Pelletier and Caventou consider as characteristic.*

SECTION VIII.—OF VULPILIN OR VULPINIC ACID.

This substance was discovered, in 1831, by M. Bebert, apothecary in Chambery, in the *evernia vulpina* of Achard, or the *lichen vulpinus* of Linnæus.†

This plant, which is a native of the South of Europe, is found in great abundance on the trees in the forests of Ausbourg, at the foot of Mount Cenis and the little St. Bernard. This lichen has a yellow colour. It is composed of filamentous expansions, the extreme divisions of which are almost capillary. When shaken it gives out a yellow powder, which occasions sneezing.

When treated by MM. Robiquet and Blondeau with alcohol, it lost its colour, while the alcohol had acquired a deep greenish-yellow colour. When the alcohol was evaporated, the solution became muddy, and the same yellow irritating substance was deposited as from the lichen itself. When the liquid was cooled it deposited a great quantity of granular crystals, of a greenish-yellow colour, which, when dried by pressure between folds of blotting paper, had a micacious appearance, mixed with a deep yellowish-green colouring matter.

This matter, treated twice successively by ether, was mostly dissolved. The solution had a deep grass-green colour. Left to spontaneous evaporation it deposited flat prisms, of a yellow colour, mixed with chlorophylle. The portion of matter not dissolved by ether had a yellow colour. Boiling alcohol dissolved it, and when left to spontaneous evaporation, deposited transparent rectangular prisms, of a fine yellow colour. These crystals constitute the *vulpilin* of Bebert. The alcohol, from which the matter treated with ether had been obtained, being evaporated to dryness, and the residue treated with ether as before, more vulpilin was obtained.

Vulpilin is transparent, and of a fine lemon-yellow colour, not altered by exposure to the air, melting when heated, and assuming its crystalline state on cooling. It may be volatilized without decomposition. It is not decomposed by concentrated nitric, sulphuric, or muriatic acids. It is but little soluble in cold water, though it

* Ann. de Chim. et de Phys. x. 167. † Jour. de Pharm. xvii. 696.

communicates to it a yellow colour. It is very soluble in boiling water, and in hot alcohol, and in ether. The aqueous solution, though evaporated to the consistence of a syrup, does not crystallize. Gelatinous alumina discolours this solution. It is precipitated by acetate of lead, chloride of tin, and the nitrates of mercury. The concentrated acids likewise render it muddy.

When heated in a crucible it swells, and is decomposed, giving out carburetted hydrogen, oil, and a little acid water, without any trace of ammonia.

Robiquet and Blondeau ascertained that the solution of vulpilin reddens vegetable blues, and that it combines with ammonia forming a salt. It is therefore an acid.

It would probably constitute an important yellow dye; and, indeed, the lichen vulpinus has been already pointed out by Bucholz as a substance employed for dying woollen cloth.

SECTION IX.—OF LACTUCIC ACID.

This acid was discovered by Pfaff, in the juice of the *lactuca virosa*. The clarified juice was precipitated by sulphate of copper, or acetate of lead. The precipitate was washed and decomposed by sulphuretted hydrogen. When the filtered liquid was evaporated, the lactucic acid precipitated in colourless crystals.

Its taste is strongly acid, and it has a great resemblance to oxalic acid; but differs from it by forming abundant green precipitates when dropt into the neutral protosalts of iron, and a brown precipitate with sulphate of copper. With magnesia it forms a little soluble salt. Its other properties have not been examined.

SECTION X.—OF VERDOUS AND VERDIC ACIDS.

Runge discovered an acid to which he gave the name of *verdic*, because it becomes green when exposed to the air, combined with an excess of base, in various families of plants, namely, the *acoraceæ*, *valerianæ*, *caprifoliæ*, *umbelliferæ*, and *plantagineæ*. The green colour is induced by the absorption of oxygen. On that account Berzelius calls the colourless acid *verdous*, and the green acid *verdic*.

The verdous acid may be obtained from the root of the *scabiosa succisa*, after having first dried it, reduced it to powder, and deprived it of its fibres. It is digested in alcohol, as long as any thing is taken up. The alcoholic solution is concentrated, and ether poured into it. The flocks which are precipitated are dissolved in water, and the solution mixed with lead. The precipitate consists of verdite of lead. It is decomposed by sulphuretted hydrogen. The filtered liquid being evaporated, we obtain the verdous acid under the form of a yellow brittle matter which reddens the infusion of litmus, and undergoes no alteration when exposed to the air. When this acid is saturated with an alkali, ammonia for example, and exposed to the air, it absorbs oxygen, and gradually assumes a green colour.

When thus altered, acids throw it down from its solutions under

the form of a brownish-red powder, which constitutes *verdic acid*. The alkalies dissolve it, and assume a green colour.

The earthy and metalline *verdites* are yellow; but the *verdates* of the same bases are green. According to Runge, verdous is changed into verdic acid by absorbing an atom of oxygen.

SECTION XI.—OF RHEIN.

This substance has been extracted from *rhubarb*, which is the root of various species of *rheum*, namely, the *palmatum*, *compactum*, *australe*, et *undulatum*, and probably even other species. These roots were analyzed with much care by Schrader, Brande, and Hornemann. The last of these chemists detected in them a peculiar principle, to which he gave the name of *rhaponticin*. It was obtained as follows:—

The rhubarb was digested in water till every thing soluble was taken up: the aqueous solution was evaporated to the consistence of an extract, and the extract mixed with water. It deposited a yellow pulverulent matter, which being washed in cold water, and dissolved in absolute alcohol at a boiling temperature, crystallized, on the cooling of the liquid, in yellow plates or needles.

This substance is destitute of taste and smell, insoluble in cold water, ether, and volatile oils; but soluble in 24 times its weight of absolute alcohol. It does not act on vegetable colours. It has not been analyzed, but appears to contain much azote, and leaves, when calcined, a charcoal difficult to burn.*

Vaudin has found, that when ether is digested with rhubarb in powder, it dissolves a reddish-yellow substance, little soluble in water, but soluble in alcohol and ether, giving a red colour to the former, and a yellow to the latter. This substance is without smell, but has a slightly bitter taste. Its solutions strike a red colour with alkalies, and a yellow with acids. Nitric acid does not destroy this substance. If, therefore, we dissolve rhubarb in nitric acid, and evaporate the solution to the consistence of a syrup (which destroys the other principles of the root), precipitate the substance with water, and wash it with cold water to free it from the adhering acid, we obtain it in a state of purity. Vaudin has given it the name of *rhëïn*.† Its characters have not been determined with accuracy.

Dr Carpenter, in 1826, published the following formula for obtaining *rhabarbarin*, which he considered as the active principle of rhubarb.‡ Boil for half an hour six pounds of coarsely bruised Chinese rhubarb in six gallons of water, acidulated with $2\frac{1}{2}$ ounces of sulphuric acid; strain the decoction, and submit the residue to a second ebullition in a similar quantity of acidulated water; strain

* Berzelius' Traité de Chimie, vi. 205.

† The *rhein*, *rhabarbarin*, *yellow resin*, *yellow matter* of different chemists are obviously different names for the same substance. The *rhabarbarine*, *caphopicrite*, and *bitter principle of rhubarb*, are also synonymes for another substance which exists in rhubarb.

‡ Annals of Philosophy (Second Series), xi. 304.

as before, and submit it again to a third ebullition. Unite the three decoctions, and add by small portions recently powdered lime, constantly stirring it, to facilitate its action on the acid decoction. When the decoction has become slightly alkaline, it deposits a red flocculent precipitate, which is to be separated by passing it through a linen cloth, and dried. After which, reduce it to powder, and digest it in three gallons of alcohol, of the specific gravity 0·837, in a water-bath for several hours, which dissolves the *rhabarbarin*. Separate this solution from the calcareous precipitate, and distil off three-fourths of the alcohol. There then remains a strong solution of rhubarb, to which add as much sulphuric acid as will exactly neutralize it, and evaporate the whole slowly to dryness. The residuum will be of a brownish-red colour, intermingled with brilliant specks, possessing a pungent styptic taste, soluble in water, and its odour that of native rhubarb.

This preparation is stated by Dr Carpenter to be a concentrated form of the active principle of rhubarb. It is of uniform strength, and may be administered safely to new born infants.

Brandes has given the following process for obtaining pure rhein. Agitate the powder of rhubarb with ether. Distil off the greatest part of the ether from the solution, and leave the residue to spontaneous crystallization. Small yellowish-brown crystals are deposited. Dry them by pressure between folds of paper. Dissolve them in boiling alcohol of 0·856 specific gravity. When the solution cools, most of the crystals are deposited. By repeating these solutions and crystallizations two or three times, the rhein may be obtained in a state of purity.*

Rhein possesses the following properties:—It is in small grains, which, when dried, assume the form of a powder, having an intense yellow colour. It is destitute of taste and smell, and when dry is not altered by exposure to the air. When heated it melts into a transparent yellow liquid; but if the heat be continued or augmented, it becomes reddish-brown, and is charred without the evolution of any ammonia. It may, however, be sublimed in a yellow smoke, which, when condensed, is a yellow powder, sometimes crystallized. It requires 1000 times its weight of cold water to dissolve it; but it is twice as soluble in boiling water. It is very little soluble in alcohol of 0·856 specific gravity. Anhydrous alcohol dissolves $\frac{1}{112}$th part of its weight of it at a boiling temperature, and $\frac{1}{480}$th when cold. These solutions redden litmus paper.

Rhein is slightly soluble in cold oil of turpentine, and oil of almonds, but more soluble in these liquids while hot. In sulphuric and nitric acid it dissolves with a dark-red colour; but water throws it down from these acids unaltered. Nitric acid may be distilled off it without producing any change.

With the saline bases it forms beautiful red compounds. The

* Annalen der Pharmacie, ix. 85. Rumicin, from *rumex patientia*, seems the same as rhein. Ibid. p. 310.

earthy and metalline compounds may be formed by double decomposition by means of the compounds of rhein with the alkalies. They are insoluble, and those containing the metallic oxides differently coloured. The compound of rhein and oxide of copper, for example, is violet.

SECTION XII.—OF POLYGALIC ACID.

This acid constitutes the peculiar principle of the root of the *polygala senega*, or *rattlesnake root*. It was first obtained by Gehlen, in a state of impurity, in 1804, and described by him under the name of *senegin*. M. Quevenne made an elaborate analysis of this root, in 1836, and first showed that its peculiar principle possessed the characters of an acid.*

Polygalic acid was obtained by him in the following way :—The root was pulverized and treated first with cold water and then with boiling water, till every thing soluble in these liquids was taken up. Both liquids had a reddish-brown colour, strongly reddened litmus paper, and possessed a bitter and pungent taste. Acetate of lead being dropt into these liquids, a dirty greyish-yellow precipitate fell, which was a compound of the colouring matter of the root with oxide of lead. Through the liquid thus freed from colouring matter, a current of sulphuretted hydrogen gas was passed, to throw down any excess of lead that might have been added. The filtered liquid was now evaporated to dryness. The solid residual matter being treated with alcohol of the sp. gravity 0·837, there was left a brown tasteles smatter, converted by nitric acid into mucic acid, and of course possessing the characters of gum.

The alcoholic solution being evaporated, left a brown matter, soluble in water, and having a sharp taste. It was the bitter principle found in senega by Feneulle. When treated with ether the greatest part of the bitter matter was removed; for after this treatment the residue was not bitter, but acrid and pungent. The extract thus deprived of these foreign matters was dissolved in water, and the solution was mixed with diacetate of lead, which formed a fine yellow precipitate consisting of polygalic acid united to oxide of lead, and not quite free from colouring matter. This precipitate is washed till sulphuretted hydrogen ceases to indicate lead in the washings. It is then mixed with water, and a current of sulphuretted hydrogen passed through it to separate the lead. The liquid is then heated, filtered, and evaporated to dryness. The dry residue is dissolved in boiling alcohol of 0·837, and filtered while hot. On cooling, a white powder is precipitated, which is polygalic acid in a state of purity. More of it is obtained by evaporating the alcohol; and an additional dose by digesting the sulphuret of lead in alcohol. Polygalic acid, thus obtained, possesses the following characters:—

It is a white powder, without smell, and appearing at first tasteless; but it soon communicates an acrid, pungent feeling to the

* Jour. de Pharmacie, xxii. 449.

mouth, and produces a painful constriction in the fauces. The powder irritates the throat and nostrils, and excites sneezing. It is not altered by exposure to the air.

When heated, in a small retort, to a temperature gradually raised to 392°, it becomes scarcely coloured, and yields only a very small quantity of acid liquid, produced, doubtless, by the decomposition of small portions of the powder immediately in contact with the glass. What remains is not sensibly altered in its properties, showing that polygalic acid is not volatile. When burnt in a glass tube no ammoniacal vapours are given off, showing that it contains no azote. When heated on platinum foil it burns with a lively flame, giving out much smoke, and leaves no residue whatever.

Polygalic acid dissolves in cold water slowly; but when the temperature is increased it dissolves in that liquid rapidly and completely. The solution reddens litmus paper. When evaporated slowly the acid is deposited in greenish, translucent scales. If, instead of allowing it to evaporate in tranquillity, we agitate continually towards the end of the process, we obtain a light, opaque, and very white matter. Polygalic acid dissolves abundantly in absolute alcohol at the boiling temperature, but most of it precipitates when the liquid cools. Alcohol of 0·915 also allows it to fall when the solution cools. Polygalic acid is insoluble in sulphuric ether, acetic ether, and the fixed and volatile oils.

The alkalies neutralize the solution of this acid, giving it a slight greenish tinge. When an excess of barytes water is added to the solution of this acid, a white precipitate falls, consisting probably of dipolygalate of barytes. If we mix together polygalate of potash and chloride of barium no precipitate falls; but if we add, in the first place, a little barytes water, then, in that case, the white precipitate appears. The protosulphate and persulphate of iron, acetate of copper, acetate of lead, and nitrate of silver, do not occasion any precipitate when added to a solution of polygalic acid; but the case is different if the acid be united to an alkali. Chloride of gold and platinum, corrosive sublimate and tartar emetic, occasion no precipitates whether the acid be free or combined with a base; but diacetate of lead and nitrate of mercury throw down abundant white precipitates.

When concentrated nitric acid is poured upon polygalic acid, a yellow solution is formed. When heat is applied, a little oxalic acid is formed, and a substance of a beautiful pale-yellow colour, which, after being washed with cold water, has an astringent and very bitter taste. Sulphuric acid has a peculiar characteristic action on polygalic acid. It gives it first a yellow colour, by degrees the outside of the mass becomes rose-red, and dissolves in the acid. When the whole is dissolved the solution assumes a violet colour, which continues for some hours very intense, and then gradually becomes fainter, assuming a greyish-blue tinge. After 24 hours all colour is gone, and a greyish precipitate, insoluble in water, has been deposited. No disengagement of gas takes place during the solution; but the

above changes do not take place unless air has access to the liquid. When tannin is added to a solution of polygalic acid the liquid becomes opal-coloured.

Polygalic acid is very weak, being incapable of separating carbonic acid or sulphuretted hydrogen from their combinations with bases. The *alkaline polygalates* are obtained by saturating the aqueous solution of polygalic acid with the respective bases; they can be procured only in the state of thin, translucent, greenish pellicles. The polygalate of magnesia gives a white precipitate, with acetate of lead and nitrate of silver; a grey, with persulphate of iron; and a green, with salts of copper. A slight excess of acid redissolves these precipitates.

Thus polygalic acid forms with the alkalies neutral uncrystallizable salts. With barytes, besides the neutral salt, it forms also a disalt. It forms also a disalt with oxide of lead. With most of the other metalline salts it forms salts, insoluble when neutral, but soluble when there is an excess of acid.

When polygalic acid was administered internally to a small-sized dog to the extent of 2 grains, it occasioned vomiting, and twice the dose produced death, after an interval of about three hours. It seems to exert a stimulant action on the mucous membranes of the stomach and intestines.

SECTION XIII.—OF CORNIC ACID.

The bark of the root of the *Cornus florida*, a tree which is a native of the United States of America, has been long employed in that country as a febrifuge. About the year 1830, Carpenter announced that he had discovered a new alkaline body in this bark, to which he gave the name of *cornin*.* In 1835, Professor Geiger of Heidleberg, examined this bark, but could find no traces of a vegetable alkali in it.† But he discovered in it a peculiar crystallized bitter substance, which possessed feeble acid properties, and which he distinguished by the name of *cornic acid*. It was obtained in the following manner:—

The pulverized bark was digested in water till every thing soluble was taken up. A solution of a brownish-red colour, and a very bitter taste, was obtained. It contained abundance of tannin, but no vegetable alkali could be detected in it. To free it from tannin it was well agitated with moist hydrated oxide of lead. The liquid became light-yellow, and was no longer capable of striking a blue with salts of iron. The liquid thus freed from tannin and most of the colouring matter, was evaporated on the water-bath to a small quantity. It was then digested in a mixture of ether and alcohol till nothing more was taken up. The undissolved portion was a yellow glutinous mass, having a slightly bitter taste.

The etherio-alcoholic solution was distilled over the water-bath to separate the alcohol and ether. It was finally evaporated to dryness

* Magaz. fur Pharm. xv. 146. † Annalen der Pharm. xiv. 206.

over the water-bath. A quantity of adhesive light-brown matter remained, having an excessively bitter taste and reacting as an acid. It was mixed with water, filtered, and to the filtered liquid twice its weight of alcohol was added. The alcoholic solution was digested with animal charcoal, and then filtered. The liquid appeared discoloured; but, when evaporated, it left a brownish acid extractive matter. It was digested in absolute alcohol, and to the solution ether was added as long as it continued to deposit any sediment. As the liquid was still coloured, it was agitated with some hydrate of lead. From the liquid, thus rendered colourless, the alcohol and ether were distilled off, and the residue being left to spontaneous evaporation, deposited cornic acid in star-shaped crystals.

Cornic acid, thus obtained, has a very bitter taste, and is very soluble in water and alcohol. It is soluble also in ether; but less so than in alcohol. Neither ammonia, nor potash, nor lime, produce any change in its aqueous solution. Tincture of nutgalls occasions no alteration. Tincture of iodine deepens the colour, but no iodine is separated. It is not altered by acetate of lead; but subacetate occasions the deposition of a granular sediment. Corrosive sublimate occasioned no precipitate; but nitrate of silver threw down a white crystalline precipitate, which was not altered by heat, showing that it contained no aldehydic acid.

When cornic acid is heated in a platinum spoon it melts very speedily, then becomes black, giving out a vapour having no smell of ammonia, takes fire and burns with a light flame, leaving a very bulky charcoal, which gradually burns away without leaving any residue. When heated with caustic potash in a glass tube it gives out no smell of ammonia; showing that it contains no azote.*

Such are the few properties of *cornic acid* determined by Geiger. Farther investigations are wanting before we know anything very precise about its nature and constitution.

SECTION XIV.—OF GENTISIN OR GENTISIC ACID.

The root of the *gentiana lutea*, under the name of *gentian*, has been long employed in medicine as a bitter; but it was not till 1819 that an attempt was made by M. Henry to ascertain the constituents of this root, and to determine the substance on which its virtues depend. In 1820, an elaborate analysis of this root was made by MM. Henry and Caventou.† They extracted a yellow coloured crystallized substance to which they gave the name of *gentianin*, and to which they ascribed the medicinal qualities of the root. They describe the mode of obtaining this substance, and give an account of its characters, one of which is, that it has an exceedingly bitter taste. In 1837, M. Leconte published a very elaborate set of experiments on gentian.‡ He found that when the yellow crystals

* Geiger found that, when a glass tube, moistened with muriatic acid, was held over the fumes, a few white vapours appeared. But it is not likely that these were owing to ammonia.

† Jour. de Pharmacie, vii. 173. ‡ Ibid. xxiii. 465.

obtained by Henry and Caventou are properly purified, they lose their bitter taste entirely, and that they possess acid characters, being capable of combining with, and neutralizing bases. On that account he gave it the name of *gentisin** or *gentisic acid.*

M. Leconte obtained his gentisin in the following manner:—The root was digested in successive portions of alcohol of 0·825, till every thing soluble in that liquid was taken up. These liquids were mixed, and the alcohol distilled off. The extract was treated with water, which dissolved the bitter extract, sugar, and an acid, and left a white solid oil, mixed with gentisin and some resin. This residue being treated with boiling alcohol of 0·871, the gentisin was dissolved, together with a little resin, and the fatty matter was left behind. Evaporate the alcoholic solution to dryness. Ether will remove any of the fatty matter that may have been dissolved. And by successive solutions and evaporations the gentisin may be rendered quite pure. It amounts to about $\frac{1}{1000}$th part of the root employed.

It has a pale yellow colour, is crystallized in long needles, and is exceedingly light. It has a peculiar but weak smell, and is destitute of taste. It has no sensible action on the animal economy. It may be exposed to the air without undergoing any alteration. At 212° it loses no weight, and experiences no change. It is not decomposed though heated to 482°. At 572° it acquires a brownish colour and is not volatilized. Cautiously heated over an alcohol lamp, it gives out some yellow vapours which are condensed on the upper part of the tube. It becomes gradually darker coloured, and at last melts, assuming the aspect of an oil. If the heat has not been carried too far, it solidifies on cooling into a brown crystalline substance.

It requires 2000 times its weight of cold water to dissolve it, but is rather more soluble in boiling water. Water acidulated with sulphuric, nitric, or muriatic acid, does not dissolve more of it than pure water. But if we add a little potash, soda or ammonia to the water, the liquid assumes a fine yellow colour, and the gentisin dissolves.

Cold alcohol dissolves but little of it, but boiling alcohol dissolves its own weight of it, and when the liquid cools the gentisin is deposited in fine needles.

Pure sulphuric ether is hardly a better solvent than water of gentisin.

The alkalies dissolve it without alteration, and form with it crystalline compounds, which Leconte considers as salts. But these compounds are very easily decomposed, showing that gentisin is an exceedingly weak acid.

The *gentisate of soda* may be formed by adding a little caustic soda to water, in which gentisin is suspended. The acid is immediately

* From Gentius, the name of the King of Illyria, after whom the plant was named. Plinii Hist. Nat. lib. xxv. c. 7.

dissolved, and the liquid assumes a fine yellow colour. Being evaporated, it leaves a mass of crystals, which being digested in boiling alcohol, of 0·871 specific gravity, dissolve in part, and are deposited in gold-coloured needles when the liquid cools. When these crystals are heated to 212° they lose 23 per cent. of their weight, and become reddish. At 482° they become brown, without being decomposed. At a red heat they melt and leave carbonate of soda.

This salt is much more soluble in water than gentisin; but water decomposes it, the acid being precipitated, and the soda dissolved. 110 parts of boiling alcohol of 0·871 dissolve 10·3 of the salt. While the same quantity of cold alcohol dissolves 7 parts. Alcohol also decomposes it as well as water. When carbonic acid gas is passed through a solution of this salt, the gentisin is thrown down white; but it recovers its yellow colour when dried.

According to the analysis of M. Leconte, this salt is composed of

Gentisic acid	54·73
Soda	4·00
Water	17·54
	76·27

This would make the atomic weight of gentisic acid, 54·73; and the crystals seem to contain 15 atoms of water.

It is proper to state that the facts ascertained by Leconte, had been observed by Trommsdorf about the same time.*

SECTION XV.—OF AMPELIC ACID.

This acid was obtained by M. Laurent, by means of the oils which he extracted by distillation of bituminous slate.†

These oils had a certain resemblance to naphtha. Their boiling points varied very much; the lowest being 176°, and the highest 572°. The oils whose boiling points lay between 176° and 302° formed ampelic acid when boiled in a retort with concentrated nitric acid.

Ampelic acid is colourless, without smell, and almost insoluble in cold water. Boiling water dissolves but little, but alcohol and ether are excellent solvents of it. Litmus paper is slightly reddened by it. Its boiling point is above 500°. If we continue the heat, it sublimes in very minute needles. Nitric acid does not act on it. Hot concentrated sulphuric acid dissolves it, and water throws it down from this solution.

When thrown on burning coals it takes fire, and partly sublimes, giving out a smell similar to that of those bodies which have been azotized by nitric acid.

With the alkalies it forms soluble salts. When much diluted, nitric acid throws down the ampelic acid in white flocks.

The remaining six acids belonging to this order are the following:—

* Jour. de Pharmacie, xxiii. 479. † Ann. de Chim. et de Phys. lxiv. 321.

1 Fungic acid.	4 Crameric.
2 Laccic.	5 Boletic.
3 Solanic.	6 Cevaetic.

These acids have been already noticed in the *Chemistry of Inorganic Bodies* (vol. ii. pp. 82, 83, 84, 107, 112, and 139), and nothing can be added to the imperfect description drawn up six years ago.

CHAPTER VI.

COMPOUND ACIDS.

It has been already stated that these acids consist of a vegetable principle, united to a strong mineral or vegetable acid. They may be divided into two sets. The first set consists of two atoms of an acid, combined with one atom of a base, which may be driven off by a stronger base. They are, strictly speaking, not acids, but acidulous or supersalts. The second set contains hyposulphuric acid, combined with an organic substance, not acting the part of a base, and not capable of being expelled by a stronger base. The following table exhibits the names and constitution of these acids, as far as it has been ascertained:—

I. Supersalts.

1 Althionic . .	$2\,(S\,O^3) + C^4\,H^5\,O + H\,O$
2 Oxalovinic .	$2\,(C^2\,O^3) + C^4\,H^5\,O + H\,O$
3 Tartrovinic .	$2\,(C^4\,H^2\,O^5) + C^4\,H^5\,O + H\,O$
4 Racemovinic .	$2\,(C^4\,H^2\,O^5) + C^4\,H^5\,O + H\,O$
5 Sulphomethylic .	$2\,(S\,O^3) + C^2\,H^3\,O + H\,O$?
6 Tartromethylic .	$2\,(C^4\,H^2\,O^5) + C^2\,H^3\,O$
7 Racemomethylic .	$2\,(C^4\,H^2\,O^5) + C^2\,H^3\,O + H\,O$
8 Phosphovinic .	$2\,(Ph\,O^{2\frac{1}{2}}) + C^4\,H^5\,O$
9 Arseniovinic .	$2\,(Ars\,O^{2\frac{1}{2}}) + 2\,(C^4\,H^5\,O)$
10 Camphovinic .	$2\,(C^{10}\,H^{7\frac{1}{2}}\,O^5) + C^4\,H^5\,O + H\,O$

II. Compound acids containing an acid, combined with an organic substance, not acting the part of a base, and not capable of being expelled by a stronger base.

1 Ethionic . .	$S^2\,O^5 + C^4\,H^4\,O + H\,O$
2 Sulphonaphthalic .	$S^2\,O^5 + C^{20}\,H^7$
3 Hyposulphonaphthalic	$2\,(S\,O^3) + C^{11}\,H^{45}$
4 Benzosulphuric .	$S^2\,O^5 + (C^{14}\,H^4\,O^2)$
5 Sulphocetic .	$S^2\,O^5$? $+ (C^{64}\,H^{32}) + 2\,(H\,O)$
6 Sulphoglyceric .	$S^2\,O^5$? $+ (C^6\,H^7\,O^5)$
7 Sulphoindigotic and hyposulphoindigotic	
8 Stearin .	$2\,(\overset{\text{Stearic acid.}}{C^{140}\,H^{134}\,O^{10}}) + \overset{\text{Glycerin.}}{C^6\,H^7\,O^5} + 2\,(H\,O)$

9	Olein . . .	2 (C^{35} H^{30} O$^{2\frac{1}{2}}$) + C^{6} H^{7} O^{5} + 2(H O)
10	Vegetosulphuric	
11	Hyponitromeconic	$\frac{1}{2}$ (Az O^{4}) + C^{10} H^{5} O^{4}
12	Xanthic . .	2 (C S^{2}) + C^{4} H^{5} O + H O
13	Hydrocarbosulphuric	C S^{2} + H S

Oleic acid.

I. SET.

SECTION I.—OF ALTHIONIC ACID.*

This name has been given by Magnus, to what was formerly called *sulphovinic acid:* and I am disposed to adopt it, for the reasons assigned in the preface to the *Chemistry of Inorganic Bodies.* Since the account of this acid in the *Chemistry of Inorganic Bodies* (vol. ii. p. 170) was drawn up, additional experiments on it have been made, chiefly by Wöhler and Liebig,† Magnus,‡ and Marchand.§ The principal object of these experiments, was to determine the composition of the acid, and particularly, whether water entered into it as an essential ingredient. It seems to be proved by the experiments of Magnus, that when equal weights of concentrated sulphuric acid and absolute alcohol are mixed together, one-half of the acid deprives the other half of all its water, while every two atoms of the anhydrous acid thus formed unites with C^{4} H^{5} O + H O (or alcohol).

Suppose four atoms of concentrated sulphuric acid:—This acid, as is well known, is composed of 1 atom acid + 1 atom water; so that the four atoms of it contain 4 atoms acid + 4 atoms water. They are resolved into 2 (S O^{3}) + 4 (H O) and 2 (S O^{3}). Now these 2 (S O^{3}) unite with (C^{4} H^{5} O + H O). Hence, the composition of althionic acid is represented by the formula 2 (S O^{3}) + (C^{4} H^{5} O + HO).

Half the acid employed, therefore, goes to the formation of althionic acid.

Now, C^{4} H^{5} O is ether, which acts the part of a base. Hence, althionic acid is, in reality, a bisalt, or a bisulphate of ether.

The althionates have been hitherto so imperfectly examined, that it would be improper to omit in this place, the few facts which have been ascertained since the *Chemistry of Inorganic Bodies* was published.

All the althionates are, in reality, double salts. They are soluble in water, and many of them are soluble also in alcohol. In general, they form large crystals, though some of them only crystallize in scales. The alkaline althionates are decomposed when heated to 392°. Water is disengaged, together with sulphurous acid, a little carbonic acid, and an oil, which Serullas considers as identical with

* A contraction of *alcoholthionic,* from θειον, sulphur, and *alcohol,* as being a compound of sulphuric acid and absolute alcohol.

† Ann. de Chim. et de Phys. xlvii. 421; and Annalen der Pharmacie, i. 37.

‡ Ibid. lii. 139. § Poggendorf's Annalen, xxxii. 454.

heavy oil of wine, but its nature has not yet been fully examined. There remains in the retort an alkaline sulphate, mixed with charcoal.

1. *Althionate of ammonia.* This salt is easily obtained, by adding carbonate of ammonia to a solution of althionate of barytes or lead, till the whole of these bases is precipitated, and then concentrating the solution. It forms large transparent crystals, but so irregular, that their shape has not been made out. They are not altered by exposure to the air, and are very soluble in water, and less so in alcohol and ether; so that these liquids throw down the salt from an aqueous solution.

Althionate of ammonia has a peculiarly bitter, saline, and cooling taste. It melts at 122°, and, when free from sulphate of ammonia, does not undergo decomposition till heated up to 226°. This is the more surprising, as most of the althionates are decomposed at a lower temperature, and none of them can be fused without alteration. This salt, when melted, gives off no water, and undergoes no alteration in its weight. At 226° it gives off alcohol, which is neither mixed with oil of wine, nor with sulphuric acid. Towards the end of the process the smell of ether becomes perceptible, and this salt increases as the heat is raised. At last sulphuric acid is given off, and finally every thing vanishes from the retort, except a small quantity of charcoal.*

2. *Althionate of potash* crystallizes in scales having a pearly lustre, and resembling boracic acid. It has a soapy feel and a bitter taste. It is very soluble in water, and undergoes little alteration when exposed to the air. When heated it melts, gives off inflammable vapour, and leaves sulphate of potash. Its constituents are

2 atoms sulphuric acid . .	10
1 atom potash . . .	6
1 atom ether . . .	4·625
	20·625†

3. *Althionate of soda* crystallizes in rectangular prisms, which effloresce in the air. It is very bitter, dissolves in twice its weight of cold, and in its own weight of boiling water. It is composed of

2 atoms sulphuric acid . .	10
1 atom soda	4
1 atom ether . . .	4·625
2 atoms water . . .	2·25
	20·875

4. *Althionate of barytes* crystallizes in beautiful square tables, not altered in the air, but which lose, *in vacuo*, 4·3 per cent. of

* Marchand, Poggendorf's Annalen, xxviii. 235.

† Dumas, Chimie appliquée aux Arts, v. 534. The analysis was made by Mr Hennell, and confirmed by Marchand.

water. It is very soluble in water, but scarcely soluble in absolute alcohol. When distilled, it gives out sulphurous acid, empyreumatic water, and heavy oil of wine.

Liebig analyzed it with great care, and determined its composition to be

2 atoms sulphuric acid .	10
1 atom barytes . . .	9·5
1 atom ether . . .	4·625
2 atoms water . . .	2·25
	26·375*

When dried *in vacuo*, it loses two atoms water.† What remains is two atoms sulphuric acid, one atom barytes, and one atom ether.

5. *Althionate of lime* was analyzed by Marchand, who found it composed of

2 atoms sulphuric acid . .	10
1 atom lime	3·5
1 atom ether . . .	4·625
2 atoms water . . .	2·25
	20·375‡

6. *Althionate of iron.* Althionic acid dissolves iron with effervescence, and the disengagement of hydrogen gas. The solution is colourless, has a sweetish taste, and is not precipitated by chloride of barium. By spontaneous evaporation we obtain four-sided prisms, having a yellowish-white colour. They effloresce in the air, and lose their transparency.§

7. *Althionate of lead.* In addition to the account of this salt, given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 651), it may be mentioned that it is very deliquescent, absorbing such a quantity of moisture as to be converted into a liquid, by a few hours' exposure to the atmosphere.

Dumas and Boullay obtained althionate of lead crystallized in silky needles, while Vogel affirms that it is incapable of being crystallized.

8. *Althionate of copper.* This salt, from the analysis of Dumas and Boullay, seems to be composed of

2 atoms sulphuric acid . .	10
1 atom oxide of copper . .	5
1 atom ether . . .	4·625
2 atoms water . . .	2·25
	21·875

* Annalen der Pharmacie, xiii. 27.

† Magnus, Ann. de Chim. et de Phys. lii. 153.

‡ Poggendorf, xxxii. 456. § Dumas, Chimie appliquée aux Arts, v. 537.

SECTION II.—OF OXALOVINIC ACID.

This acid was discovered by Mitscherlich,* and hitherto it has been but imperfectly investigated. The method of preparing it is as follows:—

Oxalic ether is dissolved in absolute alcohol, and a solution of potash in absolute alcohol is added, precisely sufficient to saturate half the acid contained in the ether. A salt soon precipitates in crystalline scales, almost insoluble in absolute alcohol. This salt is *oxalovinate of potash.* It dissolves readily in water, but there is some difficulty in obtaining it in crystals from its aqueous solution.

An excess of base converts it into oxalate and alcohol; just as would happen to oxalic ether itself.

It undergoes no change at the temperature of 212°. Its constituents are

1 atom potash . . .	6
2 atoms oxalic acid . . .	9
1 atom ether . .	4·625
	19·625

To obtain oxalovinic acid the oxalovinate of potash is dissolved in weak alcohol, and the solution filtered. Sulphuric acid being cautiously added in the requisite quantity, sulphate of potash is deposited and oxalovinic acid remains in solution.

It decomposes carbonates of barytes and lime, forming soluble oxalovinates capable of crystallizing. From oxalovinate of barytes it is easy to obtain pure oxalovinic acid.

Several bases, oxide of copper, for example, when placed in contact with this acid, decompose it, and oxalate of copper is formed. The same thing happens when we digest oxalovinate of potash with sulphates of copper, manganese, cobalt and zinc, or acetate of lead. Oxalates of these bases are formed. When oxalovinate of potash is boiled with any salt of lime oxalate of lime is formed.

When we concentrate a solution of oxalovinic acid either on the sand-bath, or *in vacuo*, we obtain for residue pure oxalic acid.

When we dissolve oxalic ether in alcohol and add to it ammonia by little and little, till a little oxamide begins to precipitate under the form of a white powder, the liquor thus prepared gives bulky crystals of a *new substance.*

While the oxalovinate of potash is decomposed by boiling it with acetate of lead, oxalate of lead being formed, this *new substance* produces nothing similar. Its constituents, according to Mitscherlich, are

6 atoms carbon . .	= 4·5
4½ atoms hydrogen . .	= 0·5625
1 atom azote . . .	= 1·75
2 atoms oxygen . .	= 2·00
	4·8125

This remarkable substance requires further investigation.

* Lehrbuch, p. 644.

SECTION III.—OF TARTROVINIC ACID.

This acid has been recently discovered and described by M. Guerin-Varry.*

Trommsdorf observed long ago, that when tartaric acid was dissolved is absolute alcohol by the assistance of heat, the liquor, though concentrated, did not deposit crystals of tartaric acid. When this liquid was saturated with carbonate of lime tartrate of lime was obtained, and a liquid containing tartaric acid, alcohol and lime. It was the knowledge of this fact that led M. Guerin-Varry to investigate the subject farther.

He dissolved tartaric acid in powder in its own weight of boiling alcohol, and kept the solution for six hours at a temperature of between 150° and 160°. The syrupy mass was then divided into two parts. The first was diluted with a great deal of water to see whether any tartaric ether would be separated; but none appeared. The other portion was mixed with four times its bulk of water and saturated with carbonate of barytes in a gentle heat. Tartrate of barytes precipitated, which was separated by the filter. The liquid being concentrated and filtered at about 120°, to get rid of some more tartrate of barytes which had precipitated, was left to spontaneous evaporation. It gradually deposited beautiful crystals of tartrovinate of barytes.

To obtain tartrovinic acid from these crystals we have only to dissolve them in water, and to add to the solution the quantity of sulphuric acid requisite to saturate exactly the barytes which they contain. The liquid must be filtered and evaporated *in vacuo*, till the solid and crystalline residue undergoes no farther loss.

Tartrovinic acid, thus obtained, has a fine white colour, is destitute of smell, and has a sweetish and agreeable acidulous taste. It crystallizes in long oblique four-sided prisms, is heavier than water, and speedily absorbs moisture from the atmosphere. It dissolves readily in water and alcohol, but is insoluble in ether. It burns with a flame similar to that of alcohol, giving out the same smell as tartaric acid does under similar circumstances.

When kept boiling for ten hours with 40 times its weight of water, it is decomposed entirely into alcohol and tartaric acid, which is deposited in beautiful crystals.

When exposed to heat it softens at 86°, and becomes more and more moist as the heat increases, and at 194° it is a thick syrup. The liquidity augments to 284°, when it begins to give off vapours. At 329° they are disengaged in such quantity that the liquid appears to be boiling. At this time alcohol, water, acetic ether, acetic acid, carbonic acid, and carburetted hydrogen are disengaged, and may be collected. At 356° the retort contains an acid having considerable analogy to that which M. Braconnot obtained by exposing tartaric acid, for an instant, to a strong heat. At 392°, besides the

* Ann. de Chim. et de Phys. lxii. 57.

above-mentioned products, a volatile oil comes over, and a liquid very similar to acetone. There remains in the retort charcoal, pyrotartaric acid, and an oily matter.

A dilute solution of tartrovinic acid, when left exposed to an atmosphere of 77°, lets fall some mucus, and a syrup containing crystals of tartrovinic acid.

Tartrovinic acid dissolves in nitric acid of specific gravity 1·3. After an hour's solution, red vapours are given off. If we now apply heat we obtain acetic acid, carbonic acid, and crystals of oxalic acid. Sulphuric acid dissolves it completely without the disengagement of any gas. When the solution is heated there are given off acetic, carbonic, and sulphurous acids, together with carburetted hydrogen and traces of sweet oil of wine.

Iron and zinc are dissolved by this acid with the disengagement of hydrogen; but it has no action on tin, even when assisted by heat.

When an aqueous solution of tartrovinic acid is let fall, drop by drop, into barytes water, a precipitate falls, which diminishes in proportion as the liquid approaches neutrality, and when the acid is once added in excess the precipitate disappears and the liquid becomes transparent. This is directly contrary to what happens when we employ tartaric acid. This acid does not occasion any precipitate in strontian water. With lime water it throws down a precipitate which disappears with an excess of acid. No precipitate appears when it is added to potash or soda, whatever be the state of the liquid.

With acetate of lead it deposits small prisms, soluble in tartrovinic acid. When these crystals are dried they have a pearly lustre and a fine white colour. With concentrated nitrate of silver it throws down a precipitate insoluble in an excess of the acid. These characters allow us to distinguish it readily from tartaric acid.

M. Guerin-Varry subjected this acid to an analysis with oxide of copper, and obtained

Carbon	40·35 or 12 atoms	=	9	or per cent.	40·45
Hydrogen	5·74 or 10 atoms	=	1·25	— —	5·61
Oxygen	53·91 or 12 atoms	=	12	— —	53·94
			22·25		100·00

These atoms are resolvable into

2 atoms tartaric acid .	C^8	H^4	O^{10}
1 atom ether . .	C^4	H^5	O
1 atom water . .		H	O
	C^{12}	H^{10}	O^{12}

It is therefore a compound of 2 atoms of tartaric acid with 1 atom of ether and 1 atom of water.

All the tartrovinates are soluble in water and little soluble in strong alcohol; but they dissolve readily in dilute alcohol. They in general crystallize easily. Most of them have a soapy feel, and they burn with a flame like that of alcohol.

The alkaline tartrovinates, when exposed to the action of heat, melt between 383° and 419°. They are decomposed when heated a few degrees above this last temperature. When thus destroyed they yield water, alcohol, acetic ether, acetic acid, a little volatile oil, carbonic acid, and carburetted hydrogen. There remains in the retort charcoal and a pyrotartrate, unless the heat has been raised too high.

When their aqueous solution is kept long boiling they are resolved into alcohol and bitartrates. When treated with an alkali at a temperature between 320° and 338°, alcohol, acetic ether, and a very bitter-tasted oily looking substance are disengaged.

The tartrovinates may be prepared either by means of tartaric acid, alcohol and a carbonate, or by double decomposition. All those hitherto examined contain water of crystallization, except the tartrovinate of silver, which is anhydrous.

1. *Tartrovinate of ammonia* may be obtained by neutralizing tartrovinic acid by carbonate of ammonia, and abandoning the solution to spontaneous crystallization. It crystallizes in silky fibres, seemingly very long oblique four-sided prisms.

2. *Tartrovinate of potash* may be obtained by decomposing tartrovinate of barytes by sulphate of potash in slight excess. The liquid, filtered and evaporated to the consistence of a syrup, and treated with alcohol to precipitate the sulphate of potash which it contains, is to be filtered anew, and then left to spontaneous crystallization.

This salt is white and has no smell. Its taste is very slightly bitter. It crystallizes in oblique prisms with angles of 124° and 56°. The acute edge of the prism is usually truncated, and the base is inclined to that edge at an angle of 112° 30′.

100 parts of water at 74° dissolve 105·83, and at a boiling temperature any quantity whatever of this salt. It is insoluble, when cold, in alcohol and pyroxylic spirit. Boiling absolute alcohol dissolves only a trace of it. It softens at 392°, and melts at 401°.

An aqueous solution of this salt exposed to the action of a gentle heat, and in contact with the atmosphere, allows bitartrate of potash to precipitate, while alcohol makes its appearance in the liquid. The precipitate is increased by long-continued boiling.

It was carefully analyzed by M. Guerin-Varry. He obtained

Carbon	32·20	or 12 atoms =	9
Hydrogen	4·44	or 10 atoms =	1·25
Oxygen	42·58	or 12 atoms =	12
Potash	20·78	or 1 atom =	6
	100·00		28·25

Or 1 atom tartrovinic acid united to 1 atom of potash.

Tartrovinic acid forms also a subsalt with potash, which possesses alkaline characters, and crystallizes in eight-sided prisms, terminated probably by an oblique base.

3. *Tartrovinate of soda* may be prepared in the same way as the tartrovinate of potash.

It is white, crystallizes in plates, sometimes rhomboidal and sometimes rectangular.

It is composed of

1 atom tartrovinic acid . .	22·25.
1 atom soda . . .	4
$2\frac{1}{2}$ atoms water . . .	2·8125
	29·0625

4. *Tartrovinate of barytes* crystallizes in oblique rhomboidal prisms. It is white, has no smell, and its taste is slightly bitter.

100 parts of water at 73° dissolve 38·12, at 212° 127·64 parts of this salt. It is insoluble in alcohol and in pyroxylic spirit. It softens at 374° and melts at 392°. It gives out, when in fusion, an odour of alcohol and ether.

It is composed of

1 atom tartrovinic acid . .	22·25
1 atom barytes . . .	9·5
1 atom water . . .	1·125
	32·875

When dried *in vacuo* it gives out two atoms water. Hence the tartrovinic acid must lose the atom of water which it usually contains.

5. *Tartrovinate of lime.* Prepared in the same way as tartrovinate of barytes. It crystallizes in white rectangular prisms or plates. At 212° it undergoes the watery fusion, and at 410° the igneous fusion. It is composed of

1 atom tartrovinic acid . .	22·25
1 atom lime	3·50
5 atoms water . . .	5·625
	31·375

6. *Tartrovinate of zinc.* Obtained by dissolving zinc with the assistance of heat in dilute tartrovinic acid.

It is white, has a very soapy feel, and crystallizes in rectangular prisms, usually occurring in groups.

7. *Sesquitartrovinate of copper.* Formed by dissolving black oxide of copper in tartrovinic acid by means of a gentle heat. It has a blue colour, effloresces when exposed to the atmosphere, and crystallizes in long silky needles. It contains 6 atoms of water.

8. *Tartrovinate of silver.* It is prepared by pouring a concentrated solution of nitrate of silver into an equally concentrated solution of tartrovinate of barytes or potash, taking care that an excess of the latter salt should be present. A multitude of prismatic crystals precipitate. They should be dried in a dark place, and washed with cold water. They should then be exposed to a temperature not exceeding 122°.

This salt is white, and crystallizes in prisms, often bulging out in the centre. It is but slightly soluble in cold water. When exposed to the light, the colour becomes first red, which gradually darkens

into brown. At 212° it undergoes decomposition, whether heated by itself or in contact with water.

It is anhydrous, and was found by M. Guerin-Varry composed of

Tartrovinic acid	.	59·47 or 21·27
Oxide of silver	.	40·53 or 54·1
		100·00

This analysis makes the atomic weight of tartrovinic acid a little less than the theoretic number. Hence it is probable that, like tartovinate of barytes, it wants the atom of water which usually exists in tartrovinic acid. This would reduce the atomic weight to 21·125, which agrees very nearly with the constitution of tartrovinate of silver.

SECTION IV.—OF RACEMOVINIC ACID.

For the knowledge of this acid, also, we are indebted to M. Guerin-Varry, who, after the discovery of tartrovinic acid, was naturally led to examine the action of racemic acid, which has the same composition with tartaric acid (if we abstract the water), upon alcohol, and the result was the discovery of racemovinic acid.*

Racemic acid being but little soluble in absolute alcohol, we must employ four parts of alcohol for one of acid. This solution we must boil slowly, taking care to pour it back into the retort when it passes into the receiver. We may stop the boiling when the liquid, after being brought to the state of a syrup, does not deposit any crystals on cooling. It is then to be diluted with water, and saturated with carbonate of barytes. The filtered liquid is to be concentrated in a temperature between 122° and 140°, and then left at rest. The racemovinate of barytes crystallizes. The crystals are easily decomposed by means of sulphuric acid, and racemovinic acid obtained in solution. It crystallizes when the liquid is properly concentrated.

Racemovinic acid thus obtained is white, without smell, and has rather a sweeter taste, than tartrovinic acid. Its crystals are very similar to those of tartrovinic acid, except that the base of the crystals of the latter acid is more inclined to the axis of the prism. The crystals are small and deliquescent.

Its relations to water, alcohol, and ether, are similar to those of tartrovinic acid. It burns also in the same way as that acid. When kept boiling in 40 times its weight of water, it is decomposed into alcohol and racemic acid, which crystallizes.

Heat, sulphuric and nitric acids, zinc, iron, and tin, act upon it, as upon tartrovinic acid. Its action on barytes water is also the same. Lime water occasions a precipitate, insoluble in an excess of racemovinic acid and water, but soluble in nitric acid. With strontian water a precipitate falls, soluble in an excess of the acid. With potash a pulverulent precipitate falls, which is very fine if there be an excess of acid present. In soda it produces an opaline precipitate, which appears a little before the liquid becomes neutral, and increases with

* Ann. de Chim. et de Phys. lxii. 70.

the quantity of acid. This precipitate is insoluble in cold water. The phenomena are the same when carbonate of soda is used.

When dropt into solutions of sulphate of lime, or sulphate of soda, it occasions no precipitate even after an interval of 24 hours.

It precipitates acetate of lead white, and throws down a white precipitate when dropt into a concentrated solution of nitrate of silver. This last precipitate is in prisms similar to those of tartrovinate of silver.

When analyzed by oxide of copper, it gave

Carbon	38·655 or 12 atoms	= 9	or per cent.		38·50
Hydrogen	5·925 or 11 atoms	= 1·375	—	—	5·88
Oxygen	55·420 or 13 atoms	=13	—	—	55·62
	100·000	23·375			100·00

These atomic numbers obviously resolve themselves into

2 atoms racemic acid . .	$C^8 H^4 O^{10}$
1 atom ether . . .	$C^4 H^5 O$
2 atoms water . . .	$H^2 O^2$
	$C^{12} H^{11} O^{13}$

Thus it differs from tartrovinic acid by containing an additional atom of water.

The remarks made in the last section on the tartrovinates apply pretty accurately to the racemovinates. It may be observed, however, that racemovinates do not by any means crystallize so regularly as the tartrovinates. Several of them contain more water than the corresponding tartrovinates, but this water may be dissipated by drying them *in vacuo*, over sulphuric acid.

1. *Racemovinate of potash* may be prepared in the same way as the tartrovinate of potash.

It is white, and has the same taste as the tartrovinate of potash; but it does not crystallize so well. The crystals are rectangular prisms, with square bases, having the edges of the base replaced by very oblique faces. When dried *in vacuo* it loses 7·65 per cent. of water. Its constituents are

1 atom racemovinic acid . .	21·125
1 atom potash	6
2 atoms water	2·25
	29·375

2. *Racemovinate of barytes* is white, and crystallizes in very small prisms concreted into tubercles. It is much more soluble in hot than in cold water. It is insoluble in alcohol and pyroxylic spirit.

It is composed of

1 atom racemovinic acid . .	21·125
1 atom barytes . . .	9·5
2 atoms water . . .	2·25
	32·875

3. *Racemovinate of silver* may be obtained in the same way as the tartrovinate of silver, and agrees with that salt in all its properties. Its constitution is also the same: for it is composed of

1 atom racemovinic acid . .	21·125
1 atom oxide of silver . .	14·5
	35·625

SECTION V.—OF SULPHOMETHYLIC ACID.

The easiest method of obtaining this acid is from sulphomethylate of barytes, which may be prepared in the following way:—

Add, by small quantities at a time, one part of pyroxylic spirit to two parts of concentrated sulphuric acid. Much heat is evolved, and the liquid contains sulphomethylic acid. To this liquid add a slight excess of barytes, filter to get rid of the sulphate of barytes, which precipitates, then pass a current of carbonic acid through the liquid, to throw down any uncombined barytes which may be present, and filter again. When this liquid is concentrated on the vapour-bath to the proper consistency, and placed under the vacuum of an air-pump, along with some quicklime, it crystallizes to the very last drop in beautiful square plates.

This salt is colourless, has a cooling taste, and effloresces when exposed to the air. It effloresces still more rapidly *in vacuo*, and becomes quite opaque. When heated it decrepitates, and effloresces without melting. A stronger heat disengages sulphurous acid, an inflammable gas, water, and neutral sulphate of methylene. Sulphate of barytes remains coloured by some particles of charcoal. When heated in an open vessel it takes fire, and leaves pure sulphate of barytes behind it.

Its constituents, as determined by the analysis of Dumas and Peligot, are

Sulphate of barytes . .	58·5
Sulphuric acid . . .	20·8
Carbon	6·02
Hydrogen	1·5
Water	10·013
	96·833
Loss (oxygen) . . .	3·167
	100·000

It is obvious that the organic matter in this salt is composed of

Carbon	6·02	or per cent.	56·33
Hydrogen	1·5	— —	14·03
Oxygen	3·167	— —	29·64
			100

These numbers approach

2 atoms carbon	= 1·5	or per cent.	52·17
3 atoms hydrogen	= 0·375	— —	13·06
1 atom oxygen	= 1·	— —	34·77
	2·875		100

Now, this is the compound to which Dumas and Peligot have given the name of hydrate of methylene, and which I have considered as methylene.

It is clear that the sulphuric acid in this salt is combined, one half of it with barytes, and the other half of it with methylene. We may represent the constitution thus:—

2 atoms sulphuric acid . .	10
1 atom barytes . . .	9·5
1 atom methylene . . .	2·875
2 atoms water . . .	2·25
	23·825

To obtain sulphomethylic acid from this salt, we have only to dissolve it in water, and to add, by little and little, as much sulphuric acid as will exactly precipitate the whole of the barytes which it contains. We then filter the liquid, and evaporate it spontaneously *in vacuo*. When it has acquired a syrupy consistency, the sulphomethylic acid, or bisulphate of methylene crystallizes in white needles.

This compound is very easily altered. *In vacuo* it is rapidly destroyed, sulphurous acid being formed. It is very acid. It dissolves in water with facility, but does not dissolve so well in alcohol. It forms double salts with all the mineral bases; and these salts are very soluble in water. When these salts, with alkaline bases, are decomposed by heat, they give out the neutral sulphate of methylene in great quantity.

The double sulphate of barytes and methylene crystallizes with great facility and regularity. That of lime is deliquescent. That of potash crystallizes in pearly plates.*

When anhydrous sulphuric acid is made to pass into pyroxylic spirit, if we dilute the liquid with water, and supersaturate with barytes, a peculiar sulphomethylate of barytes will remain in solution. It crystallizes in long slender prisms, having a rhombic base. Yet the composition of this salt is quite the same with that of common sulphomethylate of barytes.†

Oxalic, acetic, and benzoic acids, did not form compound acids with methylene.‡

SECTION VI.—OF TARTROMETHYLIC ACID.

This acid was also discovered by M. Guerin-Varry, and described by him in the same paper in which he gave an account of the tartrovinic and racemovinic acids.§

It may be obtained by dissolving, at a boiling temperature, 1 part

* Ann. de Chim. et de Phys. lviii. 54. † Ibid. lxi. 199.
‡ Ibid. lxi. 200. § Ibid. lxii. 77.

of tartaric acid in 1 part of pyroxylic spirit, and distilling the liquor to the consistence of a syrup, at a temperature under 212°. When we perceive that the distillation goes on slowly, we examine the syrup to ascertain whether it contains tartaric acid. Should any be present, the liquid which has passed into the receiver must be poured back, and the distillation repeated. If no tartaric acid be detected, we dilute the syrup with half its weight of water, and concentrate in a temperature below 212°. We obtain a thick syrup, which, when left to spontaneous evaporation, deposits crystals of tartromethylic acid; or more frequently the whole liquor concretes into a crystalline mass, which must be dried *in vacuo*.

Tartromethylic acid is white, destitute of smell, has an acid, but, at the same time, a sweet taste. It is heavier than water, and crystallizes in four-sided prisms, with right bases.

It scarcely attracts moisture from the atmosphere. Dissolves readily in cold water, and in any proportion whatever in boiling water. It is soluble also in alcohol and pyroxylic spirit; but it is very slightly soluble in ether. It burns with a flame, similar to that of pyroxylic spirit.

When its aqueous solution is kept boiling, it is decomposed into tartaric acid and pyroxylic spirit; but is not so easily decomposed by this process as tartrovinic acid.

When exposed to the action of heat it melts, then gives out water, pyroxylic spirit, acetate of methylene, and a very heavy liquid, the nature of which has not been determined.

When an aqueous solution of tartromethylic acid is exposed to spontaneous evaporation, it deposits crystals of tartromethylic acid.

With zinc, iron, and tin, it behaves as tartrovinic acid does.

With barytes, strontian, and lime water, it forms precipitates, which dissolve in a slight excess of acid. The precipitate from strontian water dissolves also in water. With potash it forms a precipitate when the liquid is a little acid. But this precipitate is not granular and crystalline as that formed with tartaric acid; it is milky, insoluble in an excess of acid, but soluble in a very large quantity of water. When examined under the microscope no appearance of crystallization can be observed.

With soda tartromethylic acid throws down an abundant precipitate as soon as the liquid contains an excess of acid. This precipitate is granular; but not crystallized. It is insoluble in an excess of acid, but dissolves in a large quantity of water.

Tartromethylic acid does not precipitate sulphate of potash or sulphate of soda. When dropt into acetate of lead it occasions a precipitate at first in flocks, but becoming pulverulent when there is an excess of acid. In this last case there appear flat prisms, disposed in the form of stars. With concentrated nitrate of silver it forms a flocky precipitate, insoluble in an excess of acid, and very little soluble in water.

It was analyzed by M. Guerin-Varry, by means of oxide of copper. He obtained

Carbon	36·44 or 10 atoms =	7·5	or per cent.	36·58
Hydrogen	4·88 or 8 atoms =	1·0	— —	4·87
Oxygen	58·68 or 12 atoms =	12·0	— —	58·55
	100·00	20·5		100·00

Now, it will be shown in a future Chapter of this work, that methylene is a compound of C^2 H^3 O.

It is obvious that the preceding atomic numbers may be resolved into

2 atoms tartaric acid .	C^8 H^4 O^{10}
1 atom methylene . .	C^2 H^3 O
1 atom water . .	H O
	C^{10} H^8 O^{12}

Thus it appears that tartromethylic acid is composed of

2 atoms tartaric acid . .	= 16·50
1 atom methylene . .	= 2·875
1 atom water . . .	= 1·125
	20·500

So that its atomic weight is 20·5.

Very few experiments have been made upon the tartromethylates; two only of them having been hitherto examined.

1. *Tartromethylate of potash* may be obtained in the same way as tartrovinate of potash.

It is white, has no smell, and crystallizes in right rectangular prisms.

It is much more soluble in hot than in cold water. It is insoluble in alcohol and in pyroxylic spirit.

When heated it softens at 302°, and becomes yellow. At 338° it gives out white vapours. At 392° it undergoes rapid decomposition. Carburetted hydrogen and carbonic acid are given out, and a liquor which contains acetate of methylene, pyroxylic spirit, acetic acid, water, and a syrupy matter.

When boiled long in water it is transformed into pyroxylic spirit and bitartrate of potash.

When dried *in vacuo* it loses 4·2 per cent. of its weight in water.

Its constituents are

1 atom tartromethylic acid .	19·375
1 atom potash . . .	6·
1 atom water . . .	1·125
	26·50

2. *Tartromethylate of barytes.*—This salt may be prepared in the same way as tartrovinate of barytes.

It is white, has a bitter taste, and crystallizes in right prisms, occasionally terminated by bihedral summits.

It is insoluble in alcohol and pyroxylic spirit. It is more soluble in hot than in cold water. It is more easily decomposed by boiling its aqueous solution than tartromethylate of potash.

When raised to a temperature of between 302° and 320°, it gives off a syrupy liquid, having an alliaceous smell, and containing water, pyroxylic spirit, acetate of methylene, and a crystallized substance, obtained by evaporation. This substance has not been much examined; but it is not oxalate of methylene.

This salt, according to the analysis of Dumas and Peligot, is composed of

1 atom tartromethylic acid .	19·375
1 atom barytes . . .	9·5
1 atom water . . .	1·125
	30

SECTION VII.—OF RACEMOMETHYLIC ACID.

For the knowledge of this acid also we are indebted to M. Guerin-Varry, who described its properties in the same paper which contains an account of the preceding acids.*

It may be obtained in the same way as the tartromethylic, substituting racemic for tartaric acid.

It is white, without smell, and has the same taste as tartromethylic acid.

It crystallizes in right rectangular prisms, having their lateral edges truncated. Water, alcohol, and ether, act upon it as on tartromethylic acid. Boiling water decomposes it into pyroxylic spirit and racemic acid, which crystallizes. But it is more difficult to decompose this acid in this way than it is to decompose tartrovinic and racemovinic acids. When its aqueous solution is left to spontaneous evaporation no decomposition takes place. It burns with a flame similar to that of pyroxylic spirit. When exposed to the action of heat it gives off the same products as tartromethylic acid. It behaves in the same way as that acid to iron, zinc, and tin.

With barytes water it gives a precipitate soluble in an excess of acid.

With strontian water the same, but the precipitate is insoluble in an excess of acid.

With lime water it gives a precipitate composed of needles. This precipitate is insoluble in an excess of acid.

With soda or its carbonate no precipitate.

With potash and an excess of acid a precipitate falls soluble in water.

Acetate and diacetate of lead are precipitated in flocks insoluble in an excess of acid.

With sulphate of potash no precipitate, even after an interval of 16 hours.

With a concentrated solution of nitrate of silver a flocky precipitate, soluble in an excess of acid.

The constituents of this acid, as determined by the analysis of M. Guerin-Varry, are

* Ann. de Chim. et de Phys. lxii. 83.

Carbon	34·20 or 10 atoms =	7·5	or per cent.	34·68
Hydrogen	5·43 or 9 atoms =	1·125	— —	5·20
Oxygen	60·37 or 13 atoms =	13	— —	60·12
	100·00	21·625		100·00

These are obviously equivalent to

2 atoms racemic acid .	$C^8 H^4 O^{10}$
1 atom methylene .	$C^2 H^3 O$
2 atoms water . .	$H^2 O^2$
	$C^{10} H^9 O^{13}$

Differing from tartromethylic acid only by containing an additional atom of water.

1. *Racemomethylate of potash* may be prepared in the same way as the tartrovinate of potash.

It is white, and destitute of smell, and crystallizes in rectangular prisms. It is more soluble in hot than in cold water. In alcohol and pyroxylic spirit it is insoluble.

When heated, it softens at 212°, and begins to be decomposed at 302°. At 338° the decomposition is more evident, and at 392° the same products are disengaged as from the tartromethylate of potash under the same circumstances. When its aqueous solution is kept long boiling the acid is decomposed into pyroxylic spirit and bitartrate of potash.

When dried *in vacuo*, it loses a quantity of water equivalent to 4·25 per cent.

When subjected to analysis this salt was found to be composed of

1 atom racemomethylic acid .	19·375
1 atom potash . . .	6
1 atom water . . .	1·125
	26·5

It is therefore exactly the same in its composition as tartromethylate of potash.

2. *Racemomethylate of barytes* may be prepared in the same way as the *tartromethylate of barytes*.

It is white, and has the same taste with the tartromethylate, crystallizes in doubly oblique four-sided prisms. The lateral faces are inclined to each other at angles of 119° and 61°. The base is inclined to one of the lateral faces at an angle of 87°, and to another at 113°.

It contains, when in crystals, four atoms of water: when exposed to the air it loses three of these atoms, becoming opaque, and assuming a satiny lustre.

When heated before its efflorescence, it softens at 140°, and at 212° gives out vapours, which condense into fine crystalline plates. It melts at 221°, at 248° it boils, at 266° it constitutes a transparent liquid, at 347° it becomes yellow, at 401° the decomposition becomes very conspicuous. The liquid in the receiver contains water,

acetate of methylene, pyroxylic spirit, and a substance in crystals which is obtained by slow evaporation.

When we apply heat to the salt after it has undergone efflorescence crystals only appear in the upper part of the retort when the temperature has been raised to 266°, and vapours do not escape in any considerable quantity till the temperature amounts to 284°.

Racemomethylate of barytes is more soluble in hot than in cold water. It is insoluble in alcohol and pyroxylic spirit.

When the effloresced salt is dried *in vacuo* it loses a quantity of water, amounting to 3·80 per cent.

The constituents of the effloresced salt are

1 atom racemomethylic acid	19·375
1 atom barytes . . .	9·5
1 atom water . . .	1·125
	30

We see from this that when dried *in vacuo* it loses its atom of water, and becomes anhydrous.

These two are the only racemomethylates hitherto examined.

SECTION VIII.—OF PHOSPHOVINIC ACID.

In the year 1807, M. Boullay, senior, showed that an ether, similar to sulphuric ether, could be formed, by distilling a mixture of phosphoric acid and alcohol.* This fact naturally led chemists, after the discovery of *althionic acid*, to expect the existence of phosphovinic acid. This suspicion was verified by M. Lassaigne, in 1820. He made a solution of phosphoric acid, of the specific gravity 1·500. This solution was introduced into a retort, and heated to the boiling point. Then alcohol, of 0·817, was let fall into it, drop by drop, till the quantity was equal to that of the acid employed. By repeated distillations he obtained sulphuric ether, mixed with a great deal of alcohol. The viscid residue in the retort was dissolved in eight times its weight of water. It was then saturated with lime, filtered, and rendered neutral. The liquid contained a soluble salt of lime. He showed that it contained phosphoric acid and the elements of alcohol or ether. He gave it the name of *phospho-vinous* acid.† But this name was afterwards changed into phosphovinic acid, as being more systematic. But it was the *Memoir* of M. Pelouze, published in 1833, which fully explained the formation and characters of this acid, and made us acquainted with its constitution.‡ Soon after, the analysis of the phosphovinate of barytes, made by M. Pelouze, was repeated by M. Liebig, who corrected a slight oversight, committed by Pelouze, relating to the water of crystallization contained in the salt, and thus rendered the constitution of the acid more intelligible.§

Phosphovinic acid is prepared in the same way as althionic

* Ann. de Chim. lxii. 192. † Ann. de Chim. et de Phys. xiii. 294.
‡ Ibid. lii. 47. § Ibid. liv. 31.

acid, for which the reader is referred to Section I. of the present Chapter.

After having dissolved the phosphovinate of barytes in water, we add to the solution dilute sulphuric acid, by little and little, as long as it occasions a precipitate. We then filter and concentrate the liquid. After the concentration has been carried to a certain point, we finish the process by placing the concentrated liquid, *in vacuo*, over sulphuric acid. We obtain a liquid of the consistence of a thick oil. It cannot be farther concentrated; but, if we continue the desiccation *in vacuo*, it undergoes decomposition, just as happens to althionic acid. Phosphovinic acid may be obtained also by decomposing phosphovinate of lead, by means of sulphuretted hydrogen gas.

It has a biting and very acid taste, is destitute of smell, colourless, and of an oleaginous consistence. It reddens litmus paper. It is soluble in all proportions in water, alcohol, and ether, and may be boiled for a long time without undergoing decomposition, when diluted with two or three times its weight of water. But when as concentrated as possible, if it be made to boil, it undergoes immediate decomposition, ether and alcohol pass over, carburetted hydrogen is disengaged, together with traces of sweet oil of wine; and there remains in the retort, phosphoric acid mixed with charcoal.

When a very concentrated solution of this acid is set aside, some crystals are deposited, the quantity of which is not increased, though the liquid be cooled down to —7°·5.

This acid coagulates albumen. No difference has been observed in the acid, whether it be prepared with phosphoric or pyrophosphoric acid.

When dilute phosphovinic acid is placed in contact with zinc or iron, hydrogen gas is disengaged, and phosphovinates of these metals formed. It decomposes the carbonates, driving off the carbonic acid gas. Like althionic acid, it contains two atoms of phosphoric acid, united with an atom of ether, and a quantity of water still undetermined, on account of the difficulty of obtaining the acid in a crystallized state.

The only phosphovinates hitherto examined are those of barytes, potash, lime, strontian, lead, and silver, for our knowledge of which we are indebted to M. Pelouze.

1. *Phosphovinate of barytes* was the salt which M. Pelouze chiefly studied, and by means of which, he determined the composition of phosphovinic acid.

To obtain it, we mix equal weights of alcohol of 0·817, and phosphoric acid of the consistence of a thick syrup, and keep the mixture, for some minutes, in a temperature of between 140° and 176°. After 24 hours we dilute the mixture, with from 7 to 8 times its weight of water, and neutralize it by carbonate of barytes in the state of a fine powder. The liquid is then brought to the state of ebullition, to volatilize the excess of alcohol. It is afterwards allowed to cool down to 158°, and passed through a filter. The liquid,

on cooling, deposits a fine white salt in hexagonal plates. This is phosphovinate of barytes.

It is white, without smell, and has a disagreeable taste, being saline and bitter at the same time. When exposed to the air it effloresces, but exceedingly slowly. It is insoluble in alcohol and ether, which precipitate it immediately from its solution in water.

Its solubility in water is remarkable. It is greatest at about 104°, and diminishes whether we increase or diminish the temperature of that liquid. M. Pelouze found, that

100 water at	32°,	dissolves	3·4 of the salt.
	41	.	3·3
	68	.	6·72
	104	.	9·36
	122	.	7·96
	131	.	8·89
	140	.	8·08
	176	.	4·49
	212	.	2·80

When heated, the phosphovinate of barytes loses a portion of its water of crystallization, amounting to about 30 per cent. of its weight, and acquires the lustre of mother-of-pearl. It does not begin to undergo decomposition till it approaches a red heat. It then gives out water, carburetted hydrogen, and slight traces of alcohol and ether. The residue is phosphate of barytes, mixed with some charcoal.

The primary form of the crystal of this salt is a short right prism, with a rhomboidal base.

When cold nitric acid is placed in contact with it, the colour becomes opaline; phosphovinic acid is disengaged, and nitrate of barytes formed. This last salt is easily separated by means of alcohol, which dissolves the phosphovinic acid, and leaves the nitrate.

When this salt is dried, and heated with carbonate of potash, it does not give out alcohol, as is the case with althionate of barytes: it does not undergo decomposition till almost red hot: the carbonate of potash seems to have no effect in hastening the decomposition.

M. Pelouze found, that the crystals of this salt, when dried at 248°, lost 30·575 per cent. of water. M. Liebig, who repeated the experiment, found the loss 29·15 per cent. He assigns, as the reason of the difference, that the dried salt rapidly attracts moisture from the atmosphere. To prevent this, he decomposed the crystals by means of oxide of copper, and calculated the quantity of water of crystallization.

M. Pelouze analyzed the dry salt, and obtained

Phosphate of barytes . .	82·80
Carbon	9·04
Hydrogen	2·26
Oxygen	5·90
	100·00

M. Liebig,* who analyzed the salt in a crystallized state, obtained

Phosphate of barytes . .	60·87
Water of crystallization . .	29·15
Carbon	6·43
Hydrogen	1·15
Oxygen	2·40
	100·00

We may consider it as a compound of

2 atoms phosphate of barytes	= 28	or per cent.		60·71
12 atoms water . .	= 13·5	—	—	29·17
1 atom ether: 4 atoms carbon	= 3	—	—	6·59
1 atom ether: 5 atoms hydrogen	= 0·625	—	—	1·36
1 atom ether: 1 atom oxygen	= 1	—	—	2·17
	46·125			100·00

It is clear, from this, that phosphovinic acid is a compound of

2 atoms phosphoric acid . .	9
1 atom sulphuric ether . .	4·625
	13·625

2. *Phosphovinate of potash.* All the succeeding phosphovinates are easily obtained, by decomposing phosphovinate of barytes with a corresponding sulphate.

Phosphovinate of potash is very difficult to crystallize; and the crystals are so confused, that their shape has not been made out. It is very deliquescent, and fuses in its water of crystallization.

The same observations apply to the *phosphovinate of soda.*

3. *Phosphovinate of strontian* crystallizes with difficulty. Like that of barytes, it is much less soluble in boiling than in warm water. It contains water of crystallization. Alcohol throws it down from its aqueous solution.

4. *Phosphovinate of lime.* It contains four atoms of water of crystallization. It is very little soluble, and precipitates under the form of small brilliant micaceous scales, when phosphovinate of barytes is poured into nitrate or muriate of lime. It dissolves readily in water, acidulated by vinegar, or phosphoric acid.

4. *Phosphovinate of lead* is the most insoluble of all the phosphovinates. It precipitates in an anhydrous state.

5. *Phosphovinate of silver*, in its aspect and little solubility, resembles the phosphovinate of lime. It is easily obtained when nitrate of silver and phosphovinate of barytes are mixed together. It contains water of crystallization, though the exact quantity has not been determined.

SECTION IX.—ARSENIOVINIC ACID.

This acid was discovered, in 1836, by M. Felix d'Arcet, and has been hitherto but imperfectly described. It is formed by causing

* Ann. der Pharmacie, vi. 149.

arsenic acid to act on alcohol, in the same way as is followed when phosphovinic acid is prepared. By saturating the mixture with carbonate of barytes, filtering and evaporating, we obtain arseniovinate of barytes. This salt, according to the analysis of d'Arcet, is composed of

Barium	27·20
Carbon	19·21
Hydrogen	3·33
Arsenic	15·31
Oxygen	34·95
	100·00*

But he conceives the true constituents to be

1 atom barium	= 8·5	or per cent.	25·56
8 atoms carbon	= 6	— —	18·05
10 atoms hydrogen	= 1·25	— —	3·75
2 atoms arsenic	= 9·5	— —	28·57
8 atoms oxygen	= 8	— —	24·07
	33·25		100·00

This would give

1 atom barytes
2 atoms arsenic acid
2 atoms of (C^4 H^9 O) or ether.

But it is obvious that the results of the analysis are utterly unreconcileable to this formula.

SECTION X.—OF CAMPHOVINIC ACID.

M. Malagutti observed that when camphoric acid is boiled with sulphuric acid or muriatic acid and alcohol, we obtain a bitter tasted syrupy substance, which is insoluble in water, but dissolves in alkaline solutions, from which it is precipitated by acids, and which is very soluble in alcohol. This substance, after having been for several days dried *in vacuo*, was found by Malagutti to be a compound of C^{24} H^{20} O^8. These numbers may be resolved into

1 atom ether . .	C^4 H^5 O
1 atom water . .	H O
And	C^{20} H^{14} O^6

Now, this last is equivalent to two atoms of anhydrous camphoric acid, so that the syrupy substance is composed of

2 atoms camphoric acid	= 22·75
1 atom ether	= 4·625
1 atom water	= 1·125
	28·5

This is the reason why M. Malagutti has distinguished it by the name of *camphovinic acid*.†

* Ann. der Pharmacie, xix. 202. † Jour. de Pharmacie, xxiii. 75.

If we distil it in a retort, over a spirit lamp, we obtain a butyraceous matter, inflammable gases, and a residue of charcoal.

If we treat the butyraceous matter with boiling alcohol, the solution on cooling deposits very long crystals, which have neither taste nor smell, and have no action on vegetable colours. When heated they melt, and may be sublimed without decomposition. Notwithstanding these characters they combine with bases, and form with them crystallizable salts. Their properties are quite different from those of camphoric acid. Malagutti analyzed them, and found them composed of C^{10} H^{7} O^{5}; so that they differ from camphoric acid by containing two additional atoms of oxygen.

When this acid is etherified by the combined action of alcohol and a powerful acid, it yields an acid the same as that produced by crystallized camphoric acid; that is to say, camphovinic acid.

The alcoholic mother leys, from which anhydrous camphoric acid has precipitated, when treated with water, furnish a pretty dense oily deposit, which, being boiled for a few minutes with a little potash, becomes very fluid. It has a peculiar smell, and disagreeable taste, and may be volatilized without decomposition. This substance was found to consist of C^{14} H^{12} O^{4}, which may be resolved into

1 atom camphoric acid .	C^{10} H^{7} O^{3}
1 atom ether . . .	C^{4} H^{5} O
	C^{14} H^{12} O^{4}

It is therefore camphoric ether.

II. COMPOUND ACIDS OF THE SECOND SET.

These have been much less completely investigated than the preceding. For the first notion of their constitution we are indebted to the sagacity of Liebig.* The subject was afterwards farther investigated by Berzelius.†

SECTION I.—OF ETHIONIC ACID.

In the year 1818, Sertuerner described three acids produced by the action of sulphuric acid on alcohol.‡ He distinguished them by the names of *proto-ethionic*, *deuto-ethionic* and *trito-ethionic;* but his account of them was so obscure and unsatisfactory, that little attention was paid to them by chemists. In 1833, M. Magnus, in his researches on the same subject, discovered three acids, which seem to be the same with those of Sertuerner. He distinguished them by the names of *althionic*, *ethionic* and *isethionic* acids.§ The first of these has been described in a preceding Section; the second will occupy the present.

When anhydrous sulphuric acid is made to pass into absolute alcohol and the temperature is allowed to rise, sulphurous acid is disengaged, and the odour of sweet oil of wine is perceived. But

* Ann. der Pharmacie, xiii. 35. † Jour. de Pharmacie, xxiii. 480.
‡ Ann. de Chim. et de Phys. xiii. 62. § Ibid. lii. 155.

if the temperature be kept low, and the process be conducted slowly, all the sulphuric acid is absorbed by the alcohol, and we obtain an oily-looking liquid, without the disengagement of any gaseous body whatever. If we employ too little alcohol, crystals of anhydrous sulphuric acid are deposited, which may be preserved for a long time under the liquid. When the alcohol is sufficient in quantity the liquid may be mixed with water without any sensible disengagement of heat.

When this aqueous solution is saturated with barytes we obtain a considerable precipitate of sulphate of barytes, and, at the same time, a soluble salt of barytes, very easily decomposed, and which can only be evaporated *in vacuo* over sulphuric acid. This salt is not an althionate of barytes; for this last salt is soluble in alcohol, crystallizes, and gives, at a high temperature, sulphurous acid and sweet oil of wine. But the new salt is not soluble in alcohol, cannot be made to crystallize, furnishes no sweet oil of wine when its temperature is elevated, but only sulphuric acid in great quantity, while a peculiar empyreumatic odour is perceptible. This new salt was analyzed by M. Magnus, who obtained.

2 atoms sulphuric acid . .	10
1 atom barytes . . .	9·5
1 atom ether . . .	4·625
	24·125

The only difference observed between the constituents of this salt and those of althionate of barytes is that the althionate contains two atoms water, while this salt contains none.

Liebig examined this salt,* and considers it as a mixture of isethionate of barytes and althionate of barytes. The presence of this last he considers as the reason why Magnus obtained in his analysis 1 per cent. more barytes, and 1 per cent. less carbon, than theory indicated. Liebig found that the solution, when saturated with carbonate of barytes, may be evaporated by heat without decomposition. When concentrated and mixed with alcohol, a white matter fell, which, being washed with alcohol and dried, became a white powder. It is remarkable that it may be exposed to a red heat in a platinum crucible and decomposed, without the peculiar frothing which characterizes the althionate of barytes. It loses no weight when heated to 212°. At 302° it gives out a smell like that of sulphuric acid and oil of wine. Liebig found that the althionic acid might be driven off by boiling the liquid before it was saturated with barytes, and that the purified acid when saturated with barytes and the solution concentrated, deposited needle-form crystals. If we now mix the liquid with alcohol, the ethionate of barytes is deposited. When this salt is washed in alcohol and dissolved in 40 times its weight of boiling water, it is deposited quite pure when the liquid cools. The crystals are oblique prisms, very like chlorate of pot-

* Ann. der Pharm. xiii. 35.

ash. They undergo no change in the air, though exposed to a heat of 392°. At a higher temperature, water, sulphurous acid and sulphur are driven off, and there remains a mixture of sulphite and sulphate of barytes. When treated with sulphuric acid and ignited, it leaves from 66·8 to 67 per cent. of sulphate of barytes. When mixed with saltpetre and carbonate of potash, and ignited, and then treated with nitric acid and chloride of barium, it gives twice as much sulphate of barytes as by the former treatment. From these facts Liebig concludes (and the opinion is very probable) that this salt consists of

1 atom hyposulphuric acid . .	9
1 atom C^4 H^4 O . . .	4·5
1 atom barytes	9·5
	23

And he considers ethionic acid as a compound of S^2 O^5 + C^4 H^4 O+H O.

There is reason, from the experiments of Liebig, to consider the isethionic acid of Magnus as identical with the ethionic.

SECTION II.—SULPHONAPHTHALIC ACID.

This acid was considered as a compound of two atoms of sulphuric acid and one atom napthaline, and has been described as such in the *Chemistry of Inorganic Bodies* (vol ii. p. 177). But the analysis of Faraday, on which this conclusion was founded, did not quite agree with it. The subject has since been investigated by Berzelius.*

The sulphonaphthalate of barytes (formed by dissolving carbonate of barytes in sulphuric acid digested on naphthaline), he found a mixture of two salts difficult to separate exactly. But he succeeded in the following way:—Evaporate the solution of these salts till a pellicle begins to appear on the surface. Then mix the liquid with twice its bulk of alcohol of 0·833. In a few minutes one of the salts begins to precipitate in a white powder. After an interval of between 12 and 16 hours the white powder ceases to precipitate. But a good deal of labour is necessary to separate the two salts completely from each other.

The salt held in solution is the true sulphonaphthalate of barytes. It crystallizes in brilliant plates, which, when dried, have a silvery aspect. It gives from 41·7 to 41·9 per cent. of sulphate of barytes. This is nearly 2 per cent. more than it would have yielded had it consisted of 2 atoms of sulphuric acid united to 1 atom of barytes. Berzelius considers it as a compound of

1 atom hyposulphuric acid .	S^2 O^5
2 atoms naphthaline . .	2 (C^{10} H^4)
1 atom barytes . . .	Ba O

But it has been recently analyzed by M. Regnault, who found its constituents to be, when dried at 356°,

* Jour. de Pharm. iv. 842.

Barytes	27·35
Sulphur	11·76
Carbon	43·15
Hydrogen	2·63
Oxygen	15·11
	100 *

Leading to the formula

1 atom barytes	= 9·5	or per cent.	27·64
2 atoms sulphur	= 4	— —	11·64
20 atoms carbon	= 15	— —	43·64
7 atoms hydrogen	= 0·875	— —	2·54
5 atoms oxygen	= 5	— —	14·54
	34·375		100

This is obviously equivalent to

1 atom barytes		
1 atom hyposulphuric acid	S^2	O^5
1 atom of . . .		C^{20} H^7
	S^2	O^3 C^{20} H^7

C^{20} H^7 is 2 atoms of naphthaline minus 1 atom of hydrogen. This hydrogen had combined with an atom of oxygen of the sulphuric acid, and thus had converted 2 atoms of that acid into 1 atom of hyposulphuric acid. The crystallized acid contains an atom of water.

M. Regnault has examined some of the sulphonaphthalates with much care.

SECTION III.—OF HYPOSULPHONAPHTHALIC ACID.

This is the acid contained in the salt precipitated in the state of white powder from the true sulphonaphthalate of barytes. It dissolves slowly in water, and less abundantly than the preceding salt. It is very little soluble even in dilute alcohol. It gives 50 per cent. of sulphate of barytes. When heated in a glass tube it gives at the instant of decomposition a little naphthaline sublimed, and an acid gas which has not a sulphureous odour, but affects the palate with the peculiar sensation given by sulphurous acid. This salt was found composed of

Sulphate of barytes	50·930	or 1	atom
Sulphuric acid .	17·507	or 1	atom
Carbon . .	29·523	or $11\frac{1}{3}$	atoms
Hydrogen . .	1·926	or 4·38	atoms
	99·886		

These numbers give the following as the constitution of the salt:

* Ann. de Chim. et de Phys. lxv. 90.

2	atoms sulphuric acid .	10
1	atom barytes . .	9·5
11	atoms carbon . .	8·25
$4\frac{1}{2}$	atoms hydrogen . .	0·5625
		28·3125

It is obvious that the base, with which the sulphuric acid was composed, was composed of C^{11} $H^{4\frac{1}{2}}$.

SECTION IV.—OF BENZOSULPHURIC ACID.

This acid was discovered and described by M. Mitscherlich in 1834.* His process for obtaining it was the following :—

Common fuming sulphuric acid is put into a phial to which *benzine* is added by small quantities at a time as long as the acid continues to dissolve it; taking care to agitate the phial well after each addition. Heat is evolved during the combination, which would injure the process. The phial therefore must be kept cool by means of cold water. The acid is now dissolved in water, which occasions the separation of a small quantity of a substance to which Mitscherlich has given the name of *sulphobenzide*. It is easily separated by the filter. The acid is now to be saturated with carbonate of barytes, and as the benzosulphate of barytes is obtained only in crystalline crusts, it is best to filter the solution and to precipitate the barytes by adding the exact quantity of sulphate of copper requisite for that purpose. When the liquid is evaporated to the requisite consistency, large crystals of benzosulphate of copper are obtained. The benzosulphates of zinc, iron, silver, potash, soda and ammonia, also crystallize quite well.

The benzosulphate of copper is dissolved in water, and the copper precipitated by a current of sulphuretted hydrogen gas. When the liquid, thus freed from copper, is concentrated to the consistence of a syrup it leaves a crystalline residue, which undergoes decomposition if we elevate the temperature too high. The benzosulphates bear a pretty high temperature without undergoing decomposition. Mitscherlich raised benzosulphate of copper to 428°, and its solution in water did not precipitate barytes water. At 338° it loses all its water. Mitscherlich, before analyzing this salt, kept it for a quarter of an hour in the temperature of 356°, to ensure the complete disengagement of the water.

M. Mitscherlich afterwards found that when benzoic acid is added to concentrated sulphuric acid it dissolves with facility; but, when the solution is diluted with water, the benzoic acid is again separated. When benzoic acid is added to anhydrous sulphuric acid, heat is evolved, and a combination takes place, the whole being converted into a viscid, translucent mass. When we dilute this mass with water, the excess of benzoic acid (if too much has been added) will separate, but a combination of the sulphuric acid and benzoic

* Poggendorf's Annalen, xxxi. 283, and xxxii. 227. Ann. de Chim. et de Phys. lxvi. 318.

acid will remain, constituting benzosulphuric acid. When this acid is saturated with carbonate of barytes, the liquid filtered, and muriatic acid added to the liquid, the benzosulphate of barytes is deposited in crystals. To obtain the salt pure let it be dissolved in twenty times its weight of water at 68°. By evaporating this solution we procure the salt in a state of purity.

It acts as an acid on vegetable blues. It undergoes no alteration in the air. When treated with smoking nitric acid and other oxydizing substances, the sulphuric acid is not disengaged. Heated to 392° it loses 10·63 per cent. of water. After this loss no more water can be driven off from it.

Mitscherlich analyzed it, and obtained from 100 parts of the salt:

Barytes . .	28·36	or 1 atom
Sulphuric acid .	29·68	or 2 atoms
Carbon . .	31·40	or 14 atoms
Hydrogen . .	1·86	or 5 atoms
Oxygen . .	8·70	or 3 atoms
	100·00	

Now benzoic acid is $C^{14}\ H^{5}\ O^{3}$.

It would appear from this that the acid is a compound of 2 atoms sulphuric acid and 1 atom benzoic acid, and that the salt consists of

1 atom benzosulphuric acid .	24·125
1 atom barytes . . .	9·5

But he satisfied himself afterwards that the true composition was

1 atom hyposulphuric acid	$Sl^{2}\ O^{5}$
1 atom of the radical of benzoic acid, minus an atom of hydrogen, or	$C^{14}\ H^{4}\ O^{2}$

If we exactly saturate the barytes in this salt with sulphuric acid, we separate it altogether, and obtain a solution of benzosulphuric acid. This solution may be boiled and evaporated at the temperature of 302° without undergoing decomposition. On cooling, the acid concretes into a crystalline mass. When left in a damp place, it absorbs moisture and runs again into a liquid. In a dry place it again loses this water and crystallizes. It may be combined in two proportions with bases. We obtain the neutral benzosulphate of barytes by the process just detailed. It dissolves readily in water, and crystallizes again by spontaneous evaporation. But the crystals are so irregular, that it has not been possible to determine their form. The other salt possesses acid properties, and is doubtless a bibenzosulphate of barytes.

Mitscherlich has examined the benzosulphates of lime, strontian, and lead, having united these bases directly with the pure acid. The bibenzosulphates of potash, soda, protoxide of iron, oxide of cobalt, oxides of copper, zinc, and magnesia, may be obtained in fine crystals. The bibenzosulphate of potash effloresces, the neutral salt with the same base attracts water in a moist atmosphere, but crystallizes again when the air is dry.

The affinity of benzosulphuric acid for bases is so great that it decomposes nitrate of barytes and chloride of barium.*

SECTION V.—OF SULPHOCETIC ACID.

When ethal is placed in contact with common sulphuric acid, without the application of heat, there is no action. But, when we apply the heat of the water-bath, and agitate very frequently, the two bodies combine, and *sulphocetic acid* is formed. The sulphocetate of potash is neutral, and in white scales, with a pearly lustre. According to the analysis of Dumas and Peligot, this acid is composed of

2 atoms sulphuric acid . .	10
1 atom $C^{64} H^{32}$ . . .	52
2 atoms water . . .	2·25
	64·25†

I have placed this acid here, because, from the analogy of sulphonaphthalic, it is probable that the acid in it is hyposulphuric.

SECTION VI.—OF SULPHOGLYCERIC ACID.

This acid was discovered by M. Pelouze, in 1836, and described by him in his paper on *glycerin*.‡

When concentrated sulphuric acid is placed in contact with half its weight of glycerin, the two substances unite without becoming coloured, but the union is attended with a great elevation of temperature. When this mixture, after cooling, is diluted with water, saturated with milk of lime, and filtered, it gives, by evaporation, a syrupy mass, which, on cooling, deposits crystals of a calcareous salt, very soluble in water, and in which the presence of sulphuric acid cannot be detected by reagents. The acid which this salt contains is the *sulphoglyceric*.

When sulphoglycerate of lime is dissolved in water, and digested with the requisite quantity of oxalic acid, the lime is separated, and the water contains only sulphoglyceric acid in solution. It is a colourless liquid, having a very acid taste, but destitute of smell. We cannot free it from water without decomposing it. When we attempt to concentrate it *in vacuo*, even at some degrees below 32°, it is resolved into sulphuric acid and glycerin, while it still retains a considerable quantity of water.

It readily decomposes all the carbonates, and forms, with the bases, a series of salts, remarkable for their great solubility in water, and for the great ease with which they undergo decomposition. The only sulphoglycerates hitherto examined and analyzed are those of lime, lead, and silver.

The sulphoglycerate of lime crystallizes in prismatic needles, which are colourless, and soluble in less than their weight of cold water, but insoluble in alcohol and ether. When heated to the temperature of between 284° and 302°, this salt is decomposed, giving

* Poggendorf's Annalen, xxxii. 227. † Jour. de Pharmacie, xxii. 320.
‡ Ann. de Chim. et de Phys. lxiii. 21.

out a strong, and excessively disagreeable smell, similar to that of tallow while distilling. It leaves a black residue, which becomes white by calcination, and consists of sulphate of lime, constituting $\frac{1}{33.3}$th of the weight of the salt.

Barytes decomposes this salt, throwing down the lime, and forming sulphoglycerate of barytes. When this last salt (containing an excess of barytes) is heated, it undergoes decomposition even below 212°. The barytes precipitates in combination with sulphuric acid, while the anhydrous glycerin combines with an atom of water, and remains uncombined in the liquid, in which it will be found when the excess of barytes is thrown down by carbonic acid.

When sulphoglycerate of lime is mixed cold with lime water, it is not decomposed, and forms no precipitate with chloride of barium; but if it be raised to the boiling temperature, it is abundantly precipitated by the same reagent. Thus we see that it undergoes the same decomposition as sulphoglycerate of barytes.

M. Pelouze analyzed sulphoglycerate of lime, and obtained from 100 of the salt:—

Lime .	14·62 or	3·5	= 1 atom
Sulphuric acid	41·79 or	10	= 2 atoms
Carbon .	18·60 or	4·45	= 6 atoms
Hydrogen	3·71 or	0·888	= 7 atoms
Oxygen .	21·28 or	5·09	= 5 atoms
	100		

The acid, therefore, is composed of 2 atoms sulphuric acid (or more probable 1 atom hyposulphuric acid) + C^6 H^7 O^5, which is the composition of anhydrous glycerin. The hydrous acid contains, besides, 2 atoms of water.

SECTION VII.—OF SULPHO-INDIGOTIC AND HYPOSULPHO-INDIGOTIC ACIDS.

The compounds to which these names are given were first examined and described by Berzelius.* To obtain them, indigo, purified either by sublimation or solution in alkalies, is to be dissolved in fuming sulphuric acid. The solution is to be diluted with from thirty to fifty times its weight of water, and the liquid passed through a filter. Pieces of flannel, previously made as clean as possible, are to be put into the solution. The flannel gradually combines with the blue-coloured acids, and assumes a deep blue colour. It is to be taken out, and other pieces of flannel are to be successively introduced till all the colouring matter has been abstracted. If the indigo employed was pure, nothing will remain at last but water, acidulated with sulphuric acid.

The pieces of flannel, which have acquired a deep blue colour, are to be washed in pure water till that liquid ceases to acquire an acid taste. They are then to be digested in water, in which some carbonate

* Traité de Chimie, vi. 79.

of ammonia has been dissolved. These acids separate from the flannel, and combine with the ammonia, and the liquid assumes a fine deep blue colour. This liquid must be decanted off, and the flannel must be well washed in pure water. If it still continues of a deep blue colour, the flannel may be digested a second, or even a third time, in water containing carbonate of ammonia in solution.

The ammoniacal liquors are now to be evaporated to dryness at the temperature of 140°, and alcohol of the specific gravity 0·833 is to be poured upon the residue. It dissolves the *hyposulpho-indigotate of ammonia*, and leaves the *sulpho-indigotate* undissolved.

To obtain the *sulpho-indigotic acid* we dissolve the sulpho-indigotate of ammonia in water, and precipitate by acetate of lead. The sulpho-indigotate of lead falls down, being insoluble in water. Let it be collected on a filter. The liquid which passes through the filter is usually blue, because it contains in solution a little indigo purple. The salt of lead is washed, mixed with water, and the lead thrown down by a current of sulphuretted hydrogen. We obtain a liquid of a light-yellow colour, containing sulphuric acid, united to reduced indigo, which becomes blue in the air after being filtered. When this liquid is evaporated to dryness, in a temperature not exceeding 122°, it leaves a solid residue, of a dark-blue colour, which is *sulpho-indigotic acid.*

This acid attracts humidity from the air, and is soluble in water and in alcohol. These solutions have a deep-blue colour. The acid has a peculiar but agreeable odour, similar to that observed when reduced indigo becomes blue by exposure to the air. Its taste is acid and astringent.

Hyposulpho-indigotic acid is obtained by mixing the alcoholic solution above mentioned with an alcoholic solution of acetate of lead. A blue salt of lead precipitates, which, being treated in the same way as sulpho-indigotate of lead, gives hyposulpho-indigotic acid, at first yellow, but becoming blue by exposure to the air. The solution from which the precipitate by the alcoholic solution of acetate of lead fell, is still blue, and yields an additional precipitate when ammonia is added, from which hyposulpho-indigotic acid may be extracted by means of sulphuretted hydrogen gas.

When hyposulpho-indigotic acid is evaporated, it dries quite well at the edges, but in the middle the mass remains moist, and attracts some moisture from the atmosphere. Its taste is acid, and most of its other properties are similar to those of sulpho-indigotic acid.

If these acids, after being dried, be heated in a distilling apparatus, they are decomposed. Sulphurous acid, sulphite of ammonia, much water, and traces of a volatile oil are disengaged. The sublimed sulphite becomes blue when dissolved in water, probably in consequence of a little indigo blue having been carried over.

When zinc or iron filings are introduced into either of these acids, the metal becomes oxydized at the expense of the indigo, which is reduced, without the disengagement of any hydrogen gas; and if an excess of acid has been employed, we obtain a yellowish-coloured

liquid, containing a salt of zinc or iron, combined with the reduced indigo, and soluble, which becomes instantly blue when in contact with oxygen or atmospherical air. This solution is the most sensible reagent that can be employed to detect the presence of oxygen in gases.

Sulphuretted hydrogen gas possesses likewise the property of reducing the indigo contained in these two acids. This is the reason why we obtain a yellow solution when we decompose the sulpho or hyposulpho-indigotate of lead by sulphuretted hydrogen. If we pass sulphuretted hydrogen gas through a solution of these indigo acids, it does not lose its blue colour even after several hours. But if we heat it to 122°, or higher, the indigo is reduced, sulphur is precipitated, and the blue colour disappears. The blue colour of these acids is also destroyed by protochloride of tin, assisted by heat.

The *sulpho* and *hyposulpho-indigotates* may be obtained by saturating the respective acids with the requisite quantity of each base. A few of them only have been hitherto examined.

1. *Sulpho-indigotate of potash.* It may be obtained by digesting the blue flannel above described in the carbonate of potash. The solution is evaporated to dryness, and the dry residue digested in alcohol, which dissolves the sulpho-indigotate, and leaves any excess of carbonate of potash that may exist. If we saturate sulpho-indigotic acid with carbonate of potash, and add a small excess of this last salt, the whole liquid is converted into a sort of jelly. This salt may be prepared on a large scale by means of the indigo of commerce. We dissolve the indigo in ten times its weight of concentrated sulphuric acid. After twenty-four hours the liquid is diluted with ten times its bulk of water, and filtered. If we saturate the acid liquid with a certain quantity of carbonate of potash, we obtain a blue precipitate, which is nothing else than the sulpho-indigotate of potash precipitated by the colourless sulphate formed at the same time.

The hyposulpho-indigotate of potash remains in solution. We collect the precipitate on a filter, and after the liquid portion has passed, we expose it to pressure between the folds of blotting paper. Mr Crum, who first described it, recommends washing it with four parts of acetate of potash dissolved in 100 parts of water, and then with alcohol to remove the acetate. While moist this salt is bulky, but when dried it contracts much, and acquires a coppery lustre.

It dissolves readily in boiling water, and during the cooling of a saturated solution it precipitates partially in flocks. Cold water dissolves one four hundred and fourtieth part of its weight of it, assuming so deep a blue colour as to become opaque. When the solution is evaporated the salt remains with a cupreous lustre.

This salt has received various names. Bergmann called it *precipitated indigo.* He considered it as the colouring matter of indigo, precipitated from its acid solution by the alkali. In Germany it is called *carmine of indigo* (*indigcarmin*); in France, *soluble indigo.* Mr Crum was the first who showed that it was a compound of in-

digo and sulphate of potash, and that salts, consisting of indigo, combined with sulphate of soda, sulphate of ammonia, &c. may also be obtained. He gave the name of *cerulin*, from its blue colour, to the soluble indigo contained in it, and that of *ceruleo-sulphates* to the salts consisting of this substance united with sulphates.

2. *Sulpho-indigotates of soda* and *ammonia* These salts are analogous to the preceding, but they are precipitated less completely. They may be prepared in the same way as the preceding salt. The ammoniacal salt is much more soluble than sulpho-indigotate of potash or soda.

The easiest way of obtaining the three salts just described, is to digest the blue flannel above mentioned in the respective alkaline carbonates. The solution is evaporated, and the residue is digested in alcohol. The alcoholic solution being evaporated, leaves the respective salts.

3. *Sulpho-indigotate of barytes.* This salt precipitates in flocks of a deep-blue colour, when the sulpho-indigotate of potash is mixed with chloride of barium. It is not completely insoluble, for the water employed to wash it always acquires a blue colour. It dissolves in boiling water, forming a deep-blue liquid, but precipitates again, as the liquid cools, in large deep-blue flocks. This salt is not precipitated by a small quantity of sulphuric acid. Sulphate of barytes has a greater affinity for the colouring matter of indigo than any other salt; and takes it even from the hyposulpho-indigotates. If we add sulphuric acid to a hyposulpho-indigotate, and then mix the liquid with chloride of barium, sulpho-indigotate of barytes precipitates.

Hyposulpho-indigotate of barytes. This salt may be obtained by mixing a concentrated solution of an hyposulpho-indigotate with chloride of barium in excess. The salt precipitates in deep-blue flocks, which may be collected on a filter, and dried by pressure.

4. *Sulpho-indigotate of lime.* It may be obtained by diluting the sulpho-indigotic acid with 40 or 50 times its weight of water, and then triturating it with white marble in powder till it becomes neutral. We then filter, washing the blue-coloured sulphate of lime remaining on the filter till it becomes red. The solution thus obtained is to be concentrated by evaporation and then mixed with alcohol. A flocky precipitate falls, red by transmitted light. It is collected on a filter, and washed by weak alcohol. In this state it is *sulpho-indigotate of lime.* It is more soluble in water than sulphate of lime, and when the solution is concentrated it falls in deep-blue flocks. When dried, it has a deep-blue colour, with a shade of purple.

Hyposulpho-indigotate of lime. To obtain this salt nothing more is necessary than to evaporate to dryness the solution from which the preceding salt was obtained, by means of alcohol. It has a cupreous lustre, and is remarkable for its beauty. It dissolves readily both in water and alcohol. When we mix its alcoholic solution with an alcoholic solution of acetate of lead we obtain a precipitate which is a hyposulpho-indigotate of lime and lead. The lead may be separated from it by means of sulphuretted hydrogen. There

then remains superhyposulpho-indigotate of lead. The taste of this salt is not acid, and it gives a very feeble acid re-action.

5. *Sulpho-indigotate of magnesia.* This salt is very soluble in water, and an excess of sulphate of magnesia does not thrown down any precipitate.

Hyposulpho-indigotate of magnesia possesses the same properties. These two salts may be separated from each other by means of alcohol. They do not absorb moisture from the atmosphere.

6. *Sulpho-indigotate of alumina.* Both the salts of alumina are soluble in water, and may be dried like the preceding salts. When we mix a solution of a sulphato-indigotate with a salt of alumina and then add ammonia to the liquid, a blue subsalt of alumina precipitates, which is pulverulent, and after desiccation has a blackish-blue colour.

7. *Sulpho-indigotate of lead.* This salt precipitates when acetate of lead is mixed with a solution of sulpho-indigotate of potash. It is in flocks, has a deep-blue colour, and is slightly soluble in water. When dried, its colour is almost black. If we precipitate sulpho-indigotate with diacetate of lead we obtain a subsulpho-indigotate of lead, which has a light-blue colour at first, but the colour deepens very much when the salt is dried. Sulphuric acid occasions a precipitate of sulphate of lead when added to a sulpho-indigotate mixed with a soluble salt of lead.

The best way of obtaining *hyposulpho-indigotate of lead* is to precipitate an alcoholic solution of hyposulpho-indigotate of ammonia by an alcoholic solution of acetate of lead. It falls in the state of a blue powder, which dissolves slowly in water, but completely. It is soluble also in alcohol. Its taste is astringent, but not in the least sweet.

Such are the facts respecting these two acids and their salts hitherto ascertained. Much still remains to be done before their nature can be considered as known. We do not know the constitution of either. There can be little doubt that the first is a compound of sulphuric acid and cerulin; though we do not know in what proportion. But there is not the least evidence that the second contains hyposulphuric acid: nor do we know in what it differs from the first acid. Indeed the kind of combination existing between the sulphuric acid and cerulin, and the part which this last substance plays in the compounds into which the two enter conjointly, are similar to nothing else known at present in the combinations into which organic bodies enter. The subject, therefore, is highly worthy of farther investigation.

SECTION VIII.—OF STEARIN.

Liebig and Pelouze* have shown that stearin is a compound of

2 atoms stearic acid . .	C^{140}	H^{134}	O^{10}
1 atom glycerin .	C^{6}	H^{7}	O^{5}
2 atoms water . .		H^{2}	O^{2}
An atom of stearin .	C^{146}	H^{143}	O^{17}

* Ann. de Chim. et de Phys. lxiii. 148.

Stearin, then, is an acid perfectly analogous to sulphoglyceric acid.

SECTION IX.—OF OLEIN.

Olein is probably in its constitution similar to stearin, or a compound of

2 atoms oleic acid .	$C^{70}\ H^{62}\ O^{7}$
1 atom glycerin . .	$C^{6}\ H^{7}\ O^{5}$
2 atoms water . .	$H^{2}\ O^{2}$
	$C^{76}\ H^{71}\ O^{14}$

SECTION X.—OF VEGETOSULPHURIC ACID.

Described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 179).

SECTION XI.—OF HYPONITROMECONIC ACID.

This acid was discovered by M. Couerbe, who described its properties, and gave an imperfect analysis of it in 1832.* He afterwards repeated his analysis, and corrected his results, in 1835.†

It may be formed by dissolving *meconin*, one of the constituents of opium, in nitric acid. At the common temperature of the atmosphere concentrated nitric acid dissolves meconin, and assumes a fine yellow colour. When a gentle heat is applied, the acid is disengaged without any evolution of nitrous gas, and some yellowish crystals make their appearance. When the evaporation is pushed far enough, and the whole is allowed to cool, a number of yellow crystals are deposited. These crystals constitute hyponitromeconic acid.

To purify them from a little nitric acid, which they still retain, let them be dissolved in boiling water. They will be deposited, as the liquid cools, in fine yellow crystals. If these crystals be dissolved in boiling alcohol, and again obtained by allowing the solution to cool, they may be considered as perfectly pure.

Hyponitromeconic acid, thus obtained, has a light-yellow colour, and crystallizes in long delicate four-sided prisms, with square bases. When heated to 302° it melts, and the greatest part of it is volatilized at 374°. The portion not volatilized dries at that temperature, and undergoes decomposition when the heat is elevated a little higher, giving out at the same time the odour of bitter almonds. When thrown on red hot charcoal it burns, and gives out a smell similar to that of the *craetaegus oxyacantha*.

It is soluble in water and alcohol, but crystallizes best from an alcoholic solution. Ether dissolves it also, and what is remarkable, the solution is quite colourless, while its solution in water or alcohol is yellow. But a few drops of ether added to either of these solutions, render them colourless.

The concentrated acids do not destroy hyponitromeconic acid. They dissolve it when assisted by a gentle heat, and allow it after-

* Ann. de Chim. et de Phys. l. 132. † Ibid. lix. 141.

wards to crystallize. When the solution is diluted with water it appears colourless, like the solution in ether; and long prisms are deposited of the greatest whiteness.

Its constituents, as determined by the latest analysis of M. Couerbe, are—

Carbon	50·60 or 10 atoms	= 7·5	or per cent.	50·0
Hydrogen	3·96 or 5 atoms	= 0·625	— —	4·2
Azote	6·36 or ½ atom	= 0·875	— —	5·8
Oxygen	39·08 or 6 atoms	= 6·0	— —	40·0
	100·00	15		100·0

But meconin is . . . $C^{10} H^5 O^4$

And half an atom nitrous acid $O^2 Az_{\frac{1}{2}}$

$C^{10} H^5 O^6 Az^{\frac{1}{2}}$

which make up the constituents of hyponitromeconic acid. Hence, this acid must be a compound of

1 atom meconin
½ atom nitrous acid

It would be better to call the acid nitromeconic acid.

It combines readily with the bases, and forms salts that have been but imperfectly examined. Potash, soda, and ammonia, dissolve it with extreme facility. The hyponitromeconate of potash is very soluble. The yellow colour of the acid is much deepened by combining it with bases—so much so, that it passes into red. When an acid is poured into any of these salts, the hyponitromeconic acid is precipitated unaltered.

The salts of iron and copper are precipitated by it, the former reddish-yellow, the second light-green. No precipitate appears when hyponitromeconic acid is added to the salts of manganese, lime, mercury, gold, or lead.

SECTION XII.—OF XANTHIC ACID.

The properties, preparation, and composition of this acid, so far as then known, have been already stated in the *Chemistry of Inorganic Bodies* (vol. ii. p. 175). In the year 1834, M. Zeise made a very accurate analysis of the *xanthate of potash.** He found the constituents of this salt to be,

Potassium	24·2867 or 1 atom	= 5	or per cent.	24·84
Sulphur	39·5760 or 4 atoms	= 8	— —	39·75
Carbon	22·5650 or 6 atoms	= 4·5	— —	22·36
Hydrogen	3·1153 or 5 atoms	= 0·625	— —	3·11
Oxygen	10·4570 or 2 atoms	= 2·0	— —	9·94
	100·0000	20·125		100

But one of the atoms of the oxygen was in combination with the potassium, constituting it potash. Hence the constituents of xanthic acid must be $S^4 C^6 H^5 O$. Now, this may be resolved into

* Poggendorf's Annalen, xxxii. 307.

2 atoms bisulphuret of carbon $S^4 C^2$
1 atom sulphuric ether $C^4 H^5 O$

It is obvious from this, that xanthic acid is a compound of two atoms bisulphuret of carbon, and one atom of ether, and that its atomic weight is 14·125.

To verify this atomic weight, M. Zeise* analyzed several neutral xanthates, and found them composed as follows:—

Xanthate of potash was sometimes prepared by saturating an alcoholic solution of potash with bisulphuret of carbon, and sometimes by adding hydrate of potash to an alcoholic solution of bisulphuret of carbon. It was dried *in vacuo*, over sulphuric acid. By analysis, this salt was found composed of

Xanthic acid . .	70·37	or 14·25
Potash . . .	29·63	or 6

By this analysis the atomic weight of xanthic acid is 14·25, differing from the theoretic number by only 0·125.

Xanthate of soda was obtained by saturating an alcoholic solution of soda with bisulphuret of carbon. When evaporated *in vacuo*, it sometimes gave a colourless salt in rhomboidal crystals, and sometimes a yellow-coloured mass, composed of needle-form crystals in tufts. The first were dissolved in alcohol, and then completely dried. The last were dissolved in water, and the solution evaporated till the needle-form crystals were deposited in such quantity as to give the whole the consistence of pap, and then subjected to pressure between folds of blotting-paper, which imbibed all the colouring matter; and the colourless crystals were fully dried *in vacuo* over sulphuric acid.

Xanthate of soda was composed of

Xanthic acid . .	1235	or 14·23
Soda . . .	347	or 4
	1582	

Xanthate of barytes was made in the following manner:—Anhydrous barytes in fine powder was put into a solution of bisulphuret of carbon in absolute alcohol. The mixture was left carefully covered for some hours. It was filtered while it contained uncombined bisulphuret of carbon. It was then put under the receiver of an air-pump, and a vacuum being made as quickly as possible, was dried over sulphuric acid.

Xanthate of barytes was composed of

Xanthic acid . .	91·18	or 14·05
Barytes . . .	62·17	or 9·5
	1534·35	23·55

Xanthate of lead was obtained, by mixing together solutions of nitrate of lead and xanthate of potash. At first there was an excess of the former salt, but afterwards xanthate of potash was added till it constituted an excess. By this method we obtain pure xanthate of

* Poggendorf's Annalen, xxxv. 487.

lead in fine powder, which may be collected on the filter, washed, and dried.

Xanthate of lead was composed of

Xanthic acid . .	4538 or 14·15
Oxide of lead . .	4487 or 14
	9025

The *xanthate of copper*, examined by M. Zeise, was a compound of xanthic acid and suboxide of copper. It cannot be formed directly, by mixing together aqueous solutions of salts. The portion subjected to analysis was obtained by mixing together alcoholic solutions of xanthate of potash and chloride of copper. The precipitate was washed first with alcohol, till that liquid was not rendered muddy by water; and then with water till the chloride of potassium was completely removed.

Xanthated suboxide of copper was composed of

Xanthic acid . .	7483 or 14·73
Suboxide of copper .	4572 or 9
	1·2055

The atomic weight of xanthic acid, deduced from the composition of these salts, with the exception of the last, comes so near 14·125, as to leave no doubt that the constitution of this acid, as determined by M. Zeise, is correct. He made numerous additional experiments, to determine the composition of xanthate of potash and xanthate of lead. He obtained

Potassium	24·287
Sulphur	39·880
Carbon	22·583
Hydrogen	3·189
Oxygen	10·061
	100·000

Numbers which serve to confirm his previous analysis.

M. Couerbe has analyzed the xanthate of potash and the xanthate of lead.* The results obtained for the first of these salts agree very closely with those of M. Zeise. But the constitution of xanthate of lead found by him, differs totally from that found by M. Zeise. According to him it is composed of

Sulphur	29·720
Carbon	16·940
Hydrogen	1·843
Oxide of lead . . .	51·497
	100·000

This would make xanthic acid $S^4\ C^6\ H^4$. It would be a compound of $S^4\ C^2$, or two atoms of bisulphuret of carbon, and $C^4\ H^4$, or an

* Ann. de Chim. et de Phys. lxi. 239.

atom of tetarto-carbohydrogen. It would differ from the xanthic acid of Zeise by the absence of an atom of water. But MM. Liebig and Pelouze repeated the analyses both of xanthate of lead and xanthate of silver, and found their composition to be exactly as stated by M. Zeise.* Hence M. Couerbe's notion, that when xanthic acid unites with metallic oxides, it always loses an atom of water, is not correct.

SECTION XIII.—OF FORMOBENZOILIC ACID.

This acid was first formed by M. Winckler. But for the knowledge of its properties and composition we are indebted to M. Liebig.†

It may be obtained by mixing the water distilled off bitter almonds with a quantity of muriatic acid, and then evaporating it. It remains in crystalline masses, mixed with sal ammoniac, from which it is easily freed by ether, which dissolves the new acid, but does not touch the sal ammoniac.

It is white, very soluble in water, has a strong acid taste, neutralizes bases, and forms with oxides of silver and copper, crystalline salts, little soluble in water. It decomposes the acetates, benzoates, and formates. When heated, it melts in its water of crystallization, and at a higher temperature it is decomposed, leaving a considerable residue of charcoal, and giving out an odour like that of peach-blossoms.

The crystallized acid, according to Liebig's analysis, is composed of

16 atoms carbon . . .	= 12
8 atoms hydrogen . . .	= 1
6 atoms oxygen . . .	= 6
	19

In the salts of silver and copper it is anhydrous, and composed of

16 atoms carbon . .	= 12
7 atoms hydrogen . .	= 0·875
5 atoms oxygen . .	= 5
	17·875

It is obvious, from this formula, that it is a compound of

1 atom formic acid . .	C^2 H O^3
1 atom hydret of benzoil .	C^{14} H^6 O^2
	C^{16} H^7 O^5

Oil of bitter almonds is a mixture of hydrocyanic acid and hydret of benzoil. The hydrocyanic acid with water, is decomposed into formic acid and ammonia.

For 1 atom of hydrocyanic acid	C^2 H Az
3 atoms water . .	H^3 O^3
	C^2 H^4 Az O^3

* Ann. de Chim. et de Phys. lxiii. 135. † Ibid. lxii. 135.

1 atom formic acid . .	C^2 H	O^3
1 atom ammonia . .	H^3 Az	
	C^2 H^4 Az	O^3

When a solution of the new acid is heated with binoxide of manganese, a strong effervescence takes place, carbonic acid is formed, and there distils over hydret of benzoil perfectly pure.

This constitutes the first well-authenticated example of an acid, formed by the combination of two organic bodies possessing the characters of acids, and capable of being formed at pleasure. Many others will, no doubt, hereafter present themselves. Doubtless, several of the acids described in this work are in this predicament.

SECTION XIV.—OF HYDROCARBOSULPHURIC ACID.

Already described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 175).

CHAPTER VII.

OF CYANOGEN AND ITS COMPOUNDS.

A FULL account has been given of cyanogen and its compounds, in the *Chemistry of Inorganic Bodies* (vol. ii. pp. 208—255). Our object here will be, to state the additions which have been made to our knowledge of this important class of compounds, since the publication of that work. For these additions, we are chiefly indebted to the genius and industry of Liebig and Wöhler.

It will be recollected that cyanogen* is a compound of 2 atoms carbon and 1 atom azote, or C^2 Az, that it combines with the supporters of combustion, and forms

1 Cyanic acid	C^2 Az + O
2 Chloride of cyanogen	$1\frac{1}{2}$ (C^2 Az) + $Chl^{1\frac{1}{2}}$
3 Bromide of cyanogen	$1\frac{1}{2}$ (C^2 Az) + $Br^{1\frac{1}{2}}$
4 Iodide of cyanogen	$1\frac{1}{2}$ (C^2 Az) + $I^{1\frac{1}{2}}$

The first of these compounds has been described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 225), under the name of *cyanous acid*, because, at that time, it was believed by chemists, that there existed another compound of cyanogen and oxygen containing two atoms of oxygen, and therefore entitled to the name of *cyanic acid*. Liebig and Wöhler overturned this opinion, by showing that the cyanic acid of Serullas contained hydrogen. It will be described

* Some very interesting experiments have been lately made by M. Pelouze and Mr Richardson, on the spontaneous decomposition of cyanogen in water. Besides azulmic acid, there was formed *hydrocyanic acid* and *carbonic acid, ammonia, urea*, and *oxalate of ammonia*.

in this Chapter under the name *cyanuric acid*, by which it was distinguished by Liebig and Wöhler.

Cyanogen was known also to combine with hydrogen, sulphur, and selenium, and to form

1	Hydrocyanic acid .	C^2 Az + H
2	Disulphuret of cyanogen	2 (C^2 Az) + S
3	Sulphuret of cyanogen	C^2 Az + S
4	Bisulphuret of cyanogen	C^2 Az + S^2*
5	Seleniet of cyanogen	C^2 Az + Se ?

These compounds having been described in detail in the *Chemistry of Inorganized Bodies*, the reader is referred to that work for these and some other analagous compounds of cyanogen, which it is needless to particularize here. But the following, having been unknown, or erroneously or imperfectly estimated, when that work was published, demand a place in the present volume:—

SECTION I.—OF CYANURIC ACID.

This acid, together with its analysis by Serullas, the discoverer of it, has been described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 227), under the name of *cyanic acid*.

Wöhler and Liebig† found that when pure urea was heated strongly in a retort, ammonia was given off abundantly, and a yellow matter remained in the retort, which was a mixture of *cyanuric acid* with some ammonia. When this matter, which is white or yellowish-white, is dissolved in hot sulphuric acid, and nitric acid dropped into the solution till all effervescence was at an end, if we mix the cold solution with water the cyanuric acid is precipitated quite pure in a white crystalline powder. It may be obtained in large crystals by evaporating the saturated solution at 160° to about one half, and then allowing it to cool slowly.

100 parts of these crystals, when dried at 212°, fall to powder, and lose 21·56 per cent. of water. Now it will appear immediately that the atomic weight of this acid is 8. Hence it follows that the crystals are composed of

1 atom cyanuric acid . .	8
2 atoms water	2·25
	10·25

Liebig and Wöhler obtained cyanurate of silver by mixing nitrate of silver and cyanurate of ammonia. It fell in white flocks, which did not become black when dried in the open air. It was anhydrous, and composed of

Cyanuric acid . .	35·55 or 8
Oxide of silver . .	64·65 or 14·5
	100

* Described and analyzed by Liebig. See Poggendorf's Annalen, xviii. 555.
† Ibid. xx. 375.

When cyanuric acid is dissolved in potash ley till the liquid refuses to take up any more, and the solution evaporated, we always obtain an acid salt. But if we mix the solution with alcohol, the neutral cyanurate of potash precipitates in fine crystalline needles. If we redissolve these needles in water, and evaporate, we again obtain an acid salt, and the solution becomes alkaline. The bisalt is but little soluble in water, and forms cubes, having considerable brilliancy. When heated the salt melts, cyanic acid is disengaged, a white insoluble matter sublimes, and cyanate of potash remains behind. It was analyzed, and found a compound of

Cyanuric acid .	15·84 or 7·92 × 2
Potash . .	6

Obviously 2 atoms cyanuric acid, and 1 atom potash.

The cyanuric acid, in an anhydrous state, being analyzed by Liebig and Wöhler, was found composed of

Carbon	27·921 or 3 atoms	= 2·25	or per cent.	27·907
Hydrogen	2·397 or $1\frac{1}{2}$ atom	= 0·1875	— —	2·327
Azote	32·575 or $1\frac{1}{2}$ atom	= 2·625	— —	32·558
Oxygen	37·107 or 3 atoms	= 3·000	— —	37·208
	100·000	8·0625		100

These atomic numbers may be resolved into $1\frac{1}{2}$ (C^2 Az) + $O^{1\frac{1}{2}}$ + $H^{1\frac{1}{2}}$ $O^{1\frac{1}{2}}$; that is to say, an atom and a half of cyanic acid, and an atom and a half of water.

SECTION II.—OF CYANIC ACID.

It was stated in the last section that cyanuric acid is resolvable into an atom of cyanic acid, C^2 Az O, and an atom of water H O. Liebig and Wöhler have shown that when anhydrous cyanuric acid is subjected to dry distillation, a volatile, transparent liquid passes over, which is a compound of 1 atom cyanic acid, and 1 atom water.* The receiver must be surrounded by a mixture of snow and salt. The anhydrous cyanuric acid is to be gradually heated to incipient ignition.

The liquid cyanic acid obtained is a colourless liquid. Its smell is strong and disagreeable, somewhat similar to that of concentrated acetic acid. It is very volatile, and when mixed with gaseous bodies, long preserves the gaseous state. It acts strongly on the eyes, occasioning a copious flow of tears. It reddens litmus, and is the most corrosive of all known acids. The smallest drop of it applied to any part of the skin produces instantly a blister, accompanied by severe pain. It is not combustible.

This liquid acid has very little permanence, so little indeed that it has been impossible to determine its characters with minute precision. When taken out of the freezing mixture, and exposed to the common temperature of the air, it becomes milky, thickens like gruel, and becomes hot. Frequent and successive explosions take

* Poggendorf's Annalen, xx. 383.

place in it, so that one is afraid of the destruction of the vessel containing it. In a short time it is converted into a white, dry, tasteless powder. This change does not occupy a longer time than five minutes. When a portion of the liquid is put into a well-closed vessel, and surrounded with ice, so as to preserve the temperature at 32°, the same alteration takes place, only it is not accompanied by explosions.

When we attempt to separate cyanic acid from its salts, by means of an acid containing water, it is immediately decomposed into carbonic acid and ammonia. When the vapour of liquid cyanic acid is passed into water, it is absorbed as rapidly as ammoniacal gas. In a short time the whole liquid becomes filled with small bubbles of carbonic acid gas. By degrees it becomes warm, and a strong effervescence takes place. The liquid, which was at first acid, becomes alkaline when evaporated, and smells strongly of ammonia. On cooling it concretes into a white opaque matter, consisting of a mixture of urea, and the white substance into which the acid spontaneously changes.

It appears, from the experiments of Wöhler and Liebig, that the liquid acid is speedily converted into carbonate of ammonia. The addition of a new portion of acid drives off the carbonic acid, and forms cyanate of ammonia. This cyanate, by uniting with an atom of water, is speedily converted into urea; while a third portion of the acid is converted into the white substance already noticed.

SECTION III.—OF INSOLUBLE CYANURIC ACID.

Liebig and Wöhler have distinguished the insoluble white matter into which cyanic acid spontaneously changes by the name of *insoluble cyanuric acid;* because though its properties be very different, its elementary constitution is identical with that of cyanuric acid. It was discovered by Liebig in 1829.* It may be obtained also by triturating together crystals of oxalic acid and cyanate of potash.

It is a white powder, without the least appearance of crystallization. It is insoluble in water, muriatic acid, and nitric acid, and is not altered by fuming nitric acid, or *aqua regia*. It dissolves readily in caustic potash, and, when the solution is evaporated, we obtain cyanurate of potash. Ammonia is disengaged during the evaporation, rendering it probable that some cyanate of potash was also present. When exposed to heat, the insoluble cyanuric acid behaves exactly as the crystallizable acid, being converted into liquid cyanic acid.

When gently heated with sulphuric acid the white powder is decomposed, pure carbonic acid gas being disengaged. In the solution we find a little ammonia, and nothing else, provided the acid employed was pure.

This white matter, being analyzed by Liebig and Wöhler, was found to consist of the same constituents as cyanuric acid, united in

* Poggendorf's Annalen, xv. 563.

the same ratios. They found further that the white matter, when dried at the temperature of 212°, lost 31·08 per cent. of water. If we consider this water as constituting 3 atoms, we have the composition:

White matter . .	68·92 or 8·065
Water . . .	31·08 or 3·79
	100·00

The number 3·79 comes as near 3·375, or 3 atoms water, as could be expected in such an experiment. Hence there can be little doubt that the white insoluble matter is isomeric with cyanuric acid.

SECTION IV.—OF CYANILIC ACID.

This acid was discovered by M. Liebig in the year 1833.*

When sulphocyanodide of potassium is decomposed in the dry way by chlorine, we obtain a yellow powder. If we carefully wash this yellow powder, mix it with chloride of potassium, and then boil it in nitric acid, it dissolves by little and little, and the solution, on cooling, deposits colourless and transparent crystals of *cyanilic acid.*

The sulphocyanodide of potassium is decomposed by chlorine more easily if we mix it with twice its weight of common salt in powder. It ought not to be brought into a state of fusion, because, under these circumstances, the action is violent, and the decomposition incomplete. The best way is to heat by a bath of solution of chloride of calcium and not to increase the heat till towards the end of the process.

At the beginning of the process chloride of sulphur passes over, but when a red heat is applied, long needles of chloride of cyanogen are deposited in the beak of the retort.

The crystals of cyanilic acid are washed with water to remove all nitric acid. They are then dissolved in hot water, and allowed to crystallize by slow cooling.

The crystals are large plates, having a metallic or pearly lustre. They contain water of crystallization, which they lose completely and with facility when kept in a warm dry room. When the anhydrous acid is submitted to distillation it yields the same products as cyanuric acid under the same circumstances; namely, hydrated cyanic acid, which changes quickly into the white substance, insoluble cyanuric acid, described in the last Section. No residual matter remains.

The composition of cyanilic acid is precisely the same as that of cyanuric. The crystals, when perfectly dried, lose 21 per cent. of water, exactly the loss sustained by hydrated cyanuric acid. When burnt with oxide of copper, the gas which comes over is a mixture of 2 volumes carbonic acid and 1 volume of azotic gas.

Liebig, in order to determine the atomic weight of this acid, analyzed the cyanilate of silver, formed by mixing nitrate of silver with cyanilate of ammonia. By a first experiment it was composed of

* Ann. de Chim. et de Phys. lvi. 40.

Cyanilic acid . .	494 or 16·31
Oxide of silver . .	439 or 14·5

By a second, it was composed of

Cyanilic acid . .	298·45 or 15·26
Oxide of silver .	283·55 or 14·5

The mean of these two analyses gives us 15·785 for the atomic weight of cyanilic acid.*

If the atomic weight be 16, as is probable from these analyses, it will follow that cyanilic acid, though the ratios of the atomic constituents be the same, yet contains twice as many atoms of each constituent as cyanuric acid. It must be 3 (C^2 Az) H^3 O^6. This would make the atomic weight 16·125, which does not deviate much from that resulting from the first analysis of cyanilate of silver.

SECTION V.—OF ALLANTOIN, OR ALLANTOIC ACID.

This is the substance described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 167), under the name of allantoic acid. MM. Liebig and Wöhler formed it artificially by mixing pure uric acid with water to the consistence of a thin pap, heating the mixture nearly to the boiling temperature, and then adding, by small quantities at a time, peroxide of lead in fine powder. An effervescence took place, carbonic acid gas was extricated, and the colour of the peroxide of lead was destroyed. When all action was at an end, the liquid was filtered. Oxalate of lead remained on the filter. The colourless liquid deposited, on cooling, crystals of *allantoin*. And when concentrated, crystals of urea were deposited. Thus by the action of peroxide of lead, uric acid was converted into *carbonic acid*, *oxalic acid*, *allantoin* and *urea :* and these were the only products.†

Liebig and Wöhler ascertained the identity of the crystals thus deposited with the allantoic acid of Lassaigne by a comparative analysis of each.

Allantoin forms colourless transparent rhombic crystals. They are hard and very brilliant. They were obtained about three lines long, and from a half to one line in thickness. It is tasteless, and does not act on litmus paper. At the temperature of 68°, one part of it requires for solution 160 parts of water. It is more soluble in boiling water, and is deposited in crystals as the solution cools. It had been already shown by C. G. Gmelin‡ not to be capable of neutralizing bases, and therefore not entitled to the name of acid: and his experiments were confirmed by those of Liebig and Wöhler. Oxide of silver constitutes, however, an exception. When a hot solution of allantoin is mixed with nitrate of silver, and ammonia dropt in as long as any precipitate falls, a white powder is obtained, which is a combination of allantoin and oxide of silver. This compound is decomposed by all dilute acids, allantoin being left behind unaltered.

* M. Liebig says that his second analysis gives the atomic weight of the acid 16·26 ; but unless there be a typographical error in the numbers given, the true atomic weight deduced from them is only 15·26.

† Poggendorf's Annalen, xli. 562. ‡ Gilbert's Annalen, lxiv. 351.

At a high temperature, allantoin is decomposed by the caustic alkalies into ammonia and oxalic acid. This decomposition is most easily obtained by means of barytes. If we dissolve allantoin in boiling hot barytes water, ammonia is disengaged, and a white powder falls, which is oxalate of barytes. When allantoin is heated with concentrated sulphuric acid, carbonic acid and carbonic oxide gases are disengaged, and ammonia remains in combination with the acid.

Allantoin was subjected to analysis in Liebig's laboratory, and found composed of

Carbon	30·20 or 4 atoms =	3	or per cent.	30·38
Hydrogen	4·04 or 3 atoms =	0·375	— —	3·80
Azote	35·27 or 2 atoms =	3·5	— —	35·44
Oxygen	30·49 or 3 atoms =	3·0	— —	30·38
	100·00	9·875		100·00

We might consider it as a compound of 2 atoms cyanogen ($2(C^2\ Az)$) and 3 atoms water ($3\ (H\ O)$).

To convert it into oxalate of ammonia we must add to it 3 atoms water. For

Allantoin . .	$C^4\ Az^2 + H^3\ O^3$
3 atoms water . .	$H^3\ O^3$
	$C^4\ Az^2 + H^6\ O^6$

Now 2 atoms oxalate of ammonia are $C^4\ O^6 + Az^2\ H^6$.

The allantoate of silver was analyzed in Liebig's laboratory, and found composed of

Allantoin . . .	56·45 or 18·79
Oxide of silver . .	43·55 or 14·5
	100

But the atomic weight of allantoin, as determined by the preceding analysis, being 9·875, two atoms will weigh 19·75 It is obvious from this that the compound consists of 2 atoms allantoin united to 1 atom of oxide of silver. The difference between 19·75 and 18·79 being 0·96, which approaches an atom of water, Liebig conceives that the 2 atoms of allantoin united with the atom of oxide of silver have lost an atom of water, so that their constitution has become $C^8\ Az^4\ H^5\ O^5$.

The knowledge of the constitution of allantoin enables us to explain the reactions which take place when uric acid and peroxide of lead are made to act on each other.

1 atom uric acid is .	$C^{10}\ Az^4\ H^4\ O^6$
1 atom urea is .	$C^2\ Az^2\ H^4\ O^2$
Remain . .	$C^8\ Az^2\ O^4$
To this add O^2 from peroxide of lead	O^2
	$C^8\ Az^2\ O^6$

These atoms are resolvable into

2 atoms oxalic acid .	C^4	O^6
2 atoms cyanogen .	C^4 Az^2	

To these 2 atoms of cyanogen, if we add 3 atoms water, we have } C^4 Az^2 H^3 O^3, or an atom of allantoin.

SECTION VI.—OF URIC ACID.

I have nothing to add to the account of this acid given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 156), except to correct the analysis. It has been subjected to a careful analysis by M. Liebig, who considers its atomic weight to be 21, the salts formerly called binurates being, in his opinion, simple urates. He considers its composition to be C^{10} H^4 Az^4 O^6. We have seen in the last Section how, by the action of peroxide of lead, it may be resolved into oxalic acid, allantoin, and urea.

APPENDIX.

ON THE METHOD OF DETECTING THE VEGETABLE ACIDS, AND OF DISTINGUISHING THEM FROM EACH OTHER.

Many of these acids have been so imperfectly examined, that it is not in our power to point out simple characters by which they may be detected. But it may be useful to mention the method of ascertaining those acids with which we are well acquainted, and which are frequently used as chemical reagents.

1. *Acetic acid.* This acid, when pure, is easily known by its smell, which is quite peculiar. It forms soluble salts with all the bases. Nitrate of mercury throws it down from several of its saline solutions; but not in all cases. It does not occasion any precipitate in a solution of albumen or gelatine, though it does in a solution of chondrin.

2. *Oxalic acid.* If we saturate this acid with ammonia, so as to form a neutral salt, the solution of this salt, though very dilute, throws down a white precipitate when dropt into a dilute solution of chloride of calcium. Neither tartaric, citric, nor malic acids, occasion an immediate precipitate when thus treated. When oxalic acid is mixed with binoxide of manganese in fine powder, or with bichromate of potash, and sulphuric acid or muriatic acid poured upon the mixture, an effervescence takes place, and carbonic acid is given off. When concentrated sulphuric acid is poured on crystals of oxalic acid, and heat applied, the acid is converted into carbonic acid and carbonic oxide gases.

3. *Tartaric*, *racemic*, *citric*, and *malic* acids may be distinguished from each other in the following way:—

Dissolve the acid to be tried in the smallest quantity of water.

To the solution add an excess of lime water, so that the mixture may restore the blue colour of reddened litmus paper.

(1.) If the acid be citric or malic, no precipitate falls; but if it be tartaric or racemic, a white precipitate appears.

(2.) If the acid be *tartaric*, the addition of a little sal ammoniac will completely redissolve the precipitate.

(3.) But if it be *racemic*, it will not be redissolved by this addition.

(4.) If into a neutral solution of tartrate of potash or soda, chloride of platinum be added, a black powder separates, which is metallic platinum. Brandes dissolved 1 grain of tartaric acid in 1000 grains of water, saturated it with potash, and added five drops of chloride of platinum. On heating the mixture, or rather boiling it, it became almost as black as ink, and a black powder gradually fell to the bottom.*

(5.) If *tartaric* acid be dropt into a solution of sulphate of lime, no precipitate falls.

(6.) But when *racemic* acid is dropt into a solution of sulphate of lime, a precipitate gradually falls.

(7.) The solution of *citric* acid gives, with lime water, *no* precipitate while *cold;* but if the mixture be raised to the boiling temperature, a copious white precipitate falls.

(8.) If the citric acid solution be very dilute, the precipitate produced by boiling disappears again when the liquid cools.

(9.) Malic acid is *not* precipitated by lime water, whether cold or hot.†

4. *Lactic acid* does not crystallize, but may be reduced to the consistence of a syrup. It has no smell, and is soluble in water, alcohol, and ether. Coagulates milk and albumen. Precipitates acetate of magnesia in the state of lactate, and the liquid acquires the smell of acetic acid. Precipitates also acetate of zinc. Does not throw down lime, strontian, or barytes water.

5. *Formic acid.* If this acid, or *formate of soda*, be added to a solution of any salt of *gold*, *platinum*, or *silver*, an effervescence takes place, carbonic acid gas is given off, and the gold, platinum, or silver is deposited in the metallic state. When formate of soda is put into a solution of corrosive sublimate, calomel is precipitated. When formic acid is dropt into a solution of nitrate of lead, formate of lead is deposited in needles.

6. *Pyrotartaric acid.* It crystallizes with ease, and has no smell. Melts at 212°. Does not render lime, strontian, or barytes water turbid. Does not precipitate salts of mercury, lime, barytes, nor sulphates of zinc, manganese, or peroxide of iron.

Pyrotartrate of potash is a deliquescent salt. This acid does not form a bisalt with potash.

7. *Pyrocitric acid* crystallizes with difficulty. Its other charac-

* Annalen der Pharm. ix. 302.

† See H. Rose, Poggendorf's Annalen, xxxi. 219.

ters have not been sufficiently investigated to enable us to distinguish it with facility from other acids should it occur.

8. *Citricic acid* crystallizes in octahedrons, and has no smell. Not very soluble in water. Melts at 322° into a transparent liquid, and gives off acrid fumes, which condense into white needles. Precipitates acetate of lead, and gives a red colour to salts of peroxide of iron.

9. *Maleic or equisetic acid* crystallizes in four-sided oblique prisms, and has no smell. Gives no precipitate with lime water. But barytes water throws down a white precipitate, speedily changed into crystalline grains. This precipitate is redissolved by an excess either of maleic acid or barytes water.

When concentrated solutions of maleate of potash and chloride of calcium are mixed, no precipitate falls. But after a few days needles of maleate of lime make their appearance. When acetate of lead is dropt into very dilute maleic acid, a precipitate falls, which speedily assumes the form of brilliant plates. When concentrated solutions of these two liquids are mixed, the whole becomes a tremulous jelly.

Maleic acid is soluble in 100 times its weight of water.

10. *Paramaleic or fumaric acid.* Crystals rhomboids or six-sided prisms. No smell. Soluble in 200 times its weight of water.

Not precipitated by lime, barytes, or strontian water. Precipitates acetate of lead, but the precipitate is redissolved when the liquid is heated, and falls, on cooling, in irregular crystals.

When dissolved in 200,000 times it weight of water, it gives a sensibly white precipitate with nitrate of silver. Paramaleate of potash throws down silver completely.

11. *Oxalhydric acid* does not crystallize, but may be dried into a white solid matter. Very deliquescent. No smell.

Precipitates lime, barytes, and strontian water; but the precipitates are redissolved by a slight excess of the acid. Throws down acetate or nitrate of lead in bulky flocks.

When heated in a glass tube it leaves a residue, which, when cooled without contact of air, and then projected into the atmosphere, becomes suddenly red-hot in globules, leaving traces of a thick vapour.

Converted into oxalic acid by nitric acid.

12. *Succinic acid.* No smell. Soluble in hot water, and crystallizes on cooling. Less soluble in alcohol, and not at all in ether. Volatile. Melts at 356°, and boils at 455°.

Chromic acid is converted into oxide by tartaric acid, but not altered by succinic. This will enable us to determine whether succinic acid be adulterated by tartaric.

Succinate of ammonia throws down peroxide of iron from a neutral solution.

When this acid is kept at the temperature of 266°, a number of fine white needles appear in the neck of the retort, consisting of the acid, combined with half an atom of water.

13. *Benzoic acid.* No smell. Melts at 248°, and boils at 473°; but sublimes in a current of air when gently heated. The sublimed salt is in flat prismatic needles or scales, having a fine white colour, and a satiny lustre.

The characters of succinic and benzoic acids resemble each other so closely, that it is very difficult to distinguish these two acids from each other by reagents. M. Macaire-Princep, however, has pointed out two reagents, which produce different effects upon them. 1. A neutral solution of benzoate of ammonia, gives, with the salts of copper, a *pale ash-coloured powder;* while succinate of ammonia gives a copious, curdy, fine green precipitate. 2. With the salts of cobalt, benzoate of ammonia gives a copious *flocky* precipitate, of a *white colour, with a slight shade of red;* while succinate of ammonia scarcely renders the liquid muddy, and a whole day elapses before a scarcely perceptible *red* precipitate falls.*

14. *Caffeic acid.* A white powder, insoluble in alcohol, but soluble in water.

Lime water colours it yellow, but occasions no precipitate, nor is it precipitated by protonitrate of mercury, or acetate, or subacetate of lead. Does not become green with chloride of iron, nor strike a green with ammoniated copper.

Barytes water throws down a yellow precipitate. Albumen a flocky precipitate. When strongly heated it gives out a smell similar to that of roasted coffee.

15. *Amygdalic acid.* Crystallizes in plates or scales. Has a slight smell of bitter almonds. Taste acid, styptic, and peculiar. When heated it melts into a yellow oily-looking fluid, which concretes on cooling into a translucent gummy-looking mass. A higher temperature drives it off in white smoke, which has the smell of hawthorn blossom.

16. *Hippuric acid.* Forms large transparent brittle crystals. When heated, melts and becomes black, while benzoic acid sublimes, and a distinct smell of bitter almonds is perceived.

17. *Cinnamonic acid.* Appears in old oil of cinnamon, in brown prisms. Soluble in boiling water, and deposited in white plates as the solution cools. Alcohol is a good solvent of it; melts at 248°, boils at 559°. When slowly heated, sublimes in brilliant plates, similar to benzoic acid. Its vapour excites coughing. Its salts are very like the benzoates.

18. *Tannin* or *tannic acid.* A white powder. Taste very astringent. Without smell. Very soluble in water. Precipitated white by muriatic, nitric, phosphoric, and arsenic acids; but not by oxalic, tartaric, lactic, acetic, citric, succinic, or selenious acid.

It precipitates glue, and strikes a black with the salts of iron. Absorbed rapidly by alumina, and forms with it a very insoluble compound.

19. *Gallic acid.* Does not precipitate solutions of glue or isin-

* Jour. de Pharmacie, xv. 529.

glass. Forms white crystals. Strikes a deep-blue colour with salts of iron. With lime, barytes, and strontian water, throws down white precipitates. With acetate of lead, a white precipitate.

Tannin and *gallic acid* may be distinguished from each other by the following characters:—In dilute solutions of gold, gallic acid strikes a greenish-blue colour, appearing brown by reflected light, and reduces the gold to the metallic state; but tannin strikes a *purple*. In solution of titanium, gallic acid strikes a tint of *brown*, scarcely perceptible, while tannin throws down *orange-red* flocks. Tannin precipitates tartar emetic *white*; gallic acid renders it *muddy* only after a certain time. Gallic acid gives a *brown* colour to the pure alkalies; to the alkaline carbonates a *brownish-yellow*, which passes into *green*. Tannin is *precipitated* by the pure alkalies and by their carbonates, and the liquid assumes a *brown* colour, which does not pass into green. The salts of morphina, strychnina, quinina, and cinchonina, are not precipitated by gallic acid, but they are by tannin.*

20. *Pyrogallic acid.* Crystals white plates. Taste bitter and cooling. With barytes and strontian water no precipitates. Changes persulphate of iron into protosulphate, and strikes a fine reddish-brown colour without occasioning any precipitate.

21. *Metagallic acid.* A black, tasteless, and very brilliant matter, insoluble in water. Dissolved easily by potash, soda, or ammonia, and precipitated by an acid in black flocks.

22. *Ellagic acid.* A light-buff, tasteless powder, insoluble in boiling water; unites and neutralizes potash, soda, or ammonia, but the salts are insoluble, but become soluble when a little alkali is previously dissolved in the water. When agitated in lime water, separates the lime. Does not melt when heated. When distilled a greenish-yellow vapour passes over, having the properties of ellagic acid.

23. *Kinic acid.* Very like tartaric acid. Soluble in $2\frac{1}{2}$ times its weight of cold water. Soluble also in alcohol. Its salts all soluble in water.

24. *Meconic acid.* Crystals transparent scales, soluble in 4 times their weight of water. When the solution is boiled, it becomes in succession yellow, red, and deep-brown. Strikes a red with the persalts of iron. When nitrate of silver is dropt into a solution of meconic acid, and a little more nitric acid is added than is sufficient to dissolve the meconate of silver, if we heat the liquid, the silver is converted into cyanodide of silver. If too much nitric acid be added, much oxalate of silver is formed, but no cyanodide.

25. *Metameconic acid.* Strikes a red with the persalts of iron. Requires 16 times its weight of water to dissolve it, while meconic acid is much more soluble.

26. *Pyromeconic acid.* Melts at 248°, and while fluid resembles an oil. May be volatilized in a gentle heat.

27. *Camphoric acid.* In feathery crystals. Taste acid and bitter.

* Pfaff, Jour. de Pharmacie, xv. 434.

Easily sublimed. Very little soluble in water, but very soluble in alcohol.

28. *Suberic acid.* A white solid, soluble in water. Melts at 255°. May be distilled over.

29. *Cahincic acid.* Crystals white needles. No smell. Soluble in 600 times its weight of water. Taste intensely bitter. Its salts do not crystallize.

30. *Crenic acid.* Yellowish-brown matter. Transparent. No smell. Does not crystallize. Taste acid and astringent. Very soluble in water and alcohol. Salts like extracts, insoluble in absolute alcohol.

31. *Apocrenic acid.* Brown, resembling a vegetable extract. Taste astringent. Slightly soluble in water and absolute alcohol. Precipitated from water in dark-brown flocks by sal ammoniac.

32. *Sebacic acid.* White needles, having a pearly lustre. No smell and little taste. May be volatilized. When a strong acid is poured into a concentrated solution of a sebate, sebacic acid is separated. Precipitates acetate and nitrate of lead, nitrate of silver, acetate, and nitrate of mercury.

33. *Valerianic acid.* A colourless oleaginous liquid. Smell analogous to that of valerian, but more disagreeable. Taste acid, and very unpleasant. Specific gravity 0·944. Does not congeal at—6°. Burns like an oil, and stains paper like an oil. Boils at 270°, but evaporates at a much lower temperature. Dissolves in 30 times its weight of water. Very soluble in alcohol.

34. *Roccellic acid.* A solid, fatty-looking matter. Congeals at 251° into a crystalline mass. Insoluble in water. Soluble in boiling alcohol, and crystallizes in needles when the solution cools. Burns like tallow.

35. *Anchusic acid.* A deep-red, resinous-looking matter. Insoluble in water, but soluble in alcohol and ether. Its salts of ammonia, fixed alkalies, and alkaline earths, also soluble in alcohol and ether. May be sublimed. When heated, emits violet-coloured vapour like iodine.

36. *Carbazotic acid.* Fine yellow plates having a silky lustre. Taste intensely bitter. Melts when heated, and may be volatilized. Burns with a yellow flame, and leaving a residue of charcoal. Little soluble in cold, but very soluble in hot water. Solution has a deep-yellow colour. Soluble in alcohol and ether.

37. *Indigotic acid.* Snow-white needles, having a silky lustre. Taste slightly bitter. Very little soluble in cold, but very soluble in boiling water. Solution colourless. Acid volatile. When heated, melts, and crystallizes on cooling in six-sided prisms. Nitric acid converts it into carbazotic acid.

38. *Cyanilic acid.* Large plates, having a metallic and pearly lustre.

I shall here give the method of detecting *hydrocyanic acid*, as it may be of importance to be able to do so, when poisoning is supposed to have been effected by this formidable substance.

(1.) One part of this acid, dissolved in 10,000 parts of water, may be detected by dropping into the solution a little persulphate of iron. The blue tinge communicated by the acid is quite perceptible.

(2.) One part of this acid, dissolved in 20,000 parts of water, may be detected by sulphate of copper. The process, as contrived by M. Lassaigne, is the following:—To the liquid supposed to contain hydrocyanic acid, add a few drops of hydrate of potash, so as to render it slightly alkaline; then let fall into it a very little sulphate of copper dissolved in water, and immediately after, as much muriatic acid as will be sufficient to dissolve the oxide of copper disengaged by the alkali. The liquid will remain more or less milky, according to the quantity of hydrocyanic acid present. When it amounts only to $\frac{1}{20000}$th of the whole, the milkyness disappears after an interval of some hours.

When an animal is poisoned with hydrocyanic acid, the smell of that acid is perceptible in the brain, spinal-marrow, and thorax. It is not so perceptible in the stomach; but when that organ is cut in pieces, the smell develops itself. Yet the presence of the acid in the brain and spinal-marrow cannot be detected either by persulphate of iron, or sulphate of copper. But if we distil off a portion of the liquid found in the stomach, we may almost always discover the acid in the liquid which passes over. By this method, we can discover the existence of the poison 48 hours after death.*

M. O. Henry has improved the above processes somewhat, and it may be right to state his method.† If the acid be simply in solution in water, he drops in a little nitrate of silver, which occasions a curdy precipitate. If the acid be in the liquid contained in the stomach, it must be distilled into a receiver containing a very dilute solution of nitrate of silver. Collect the cyanuret of silver, and heat it gently with about half its weight of common salt. Digest and filter. To the filtered liquid add a little perchloride or persulphate of iron. A blue colour is immediately produced.

* Lassaigne, Ann. de Chim. et de Phys. xxvii. 200.

† Jour. de Pharmacie, xxiii. 23.

CLASS II.

OF VEGETABLE ALKALIES.

These alkaline bodies, which amount at present to about 37, have all been discovered since the year 1817. Their number is augmenting every day. Almost all the plants, which are remarkable for their poisonous or medicinal properties, when subjected to a chemical examination, have been found to contain an alkaline principle. For the discovery of almost all the bodies belonging to this class, we are indebted to the chemists on the Continent. The numerous eminent chemists belonging to the Society of Apothecaries in Paris have signalized themselves in this important field in a remarkable manner, as may be seen by consulting the *Journal de Pharmacie*, which has been for many years published in monthly parts, by that eminent and industrious body. Several of the German chemists have also distinguished themselves in this popular branch of chemistry, especially Liebig, to whom we are indebted for a greater number of vegetable analyses, performed with the most rigid attention to accuracy, than to any other living chemist, unless Dumas constitute an exception.

In the present state of our knowledge, it will be convenient to divide the vegetable alkaline bodies into two orders. In the first order, all those will have a place which have been investigated sufficiently, to leave no doubt of their alkaline nature. The second order will include those which have been less perfectly examined, but which, in all probability, will be found to possess alkaline properties, when chemists shall have found leisure to investigate them with the necessary minuteness.

It has been found that all the vegetable alkalies are precipitated by tannin, or infusion of nutgalls; but not by gallic acid. M. O. Henry has found that these precipitates, which are usually white powders, are bitannates of the alkali, insoluble in cold water, and easily decomposed by an alkaline or earthy base. He has proposed infusion of nutgalls as an excellent reagent for obtaining these alkalies in a separate state. His process is this:—Digest the plant containing the alkali in warm water, acidulated with sulphuric acid. Draw off the clear liquid, neutralize it by potash, and add a concentrated infusion of nutgalls as long as a precipitate falls. Separate the precipitate, wash it with cold water, and mix it intimately with a slight excess of slacked lime. Dry the mixture over the vapour-bath till it is reduced to powder. Digest this powder in alcohol or ether. Filter, distil off the alcohol or ether. Set the residue aside for some days. The alkali will be deposited in crystals.*

* Jour. de Pharmacie, xxi. 213.

CHAPTER I.

ALKALIES ANALYZED.

The bodies belonging to this order are 21 in number. They are all compounds of four different substances—namely, carbon, hydrogen, azote, and oxygen. The chemists on the Continent have distinguished these alkaline bodies by a name commonly derived from the plant, or part of the plant, in which they are respectively found; and this name they invariably terminate in the syllable *in* or *ine*—thus *morphin* is the name of the first alkali obtained from opium by Sertuerner. This method of naming is applied to all new vegetable bodies without distinction. But the number of them has now become so great, that it would be of importance to vary the termination, in order to designate more readily the class to which the respective vegetable substances belong. In the last edition of this work, I described five of these vegetable alkalies, all that were known at the time, and distinguished them by making the name of each terminate in *a*, that they might resemble *potassa*, *soda*, and *ammonia*, all of which, in our language, are made by chemists to terminate in *a*. This rule having been generally adopted by British chemists, it will be right to continue to adopt it. I shall, therefore, distinguish the vegetable alkalies, by making them terminate in *a*: that is to say, I will adopt, without change, the Latin names for these alkalies, assigned them in the foreign *Pharmacopœias*. The neutral vegetable principles may be allowed to terminate in *in*. Thus *morphina* is an alkali, as the termination shows, while *meconin* is a neutral substance.

The following table exhibits the names and composition of the different vegetable alkalies hitherto analyzed, arranged according to the number of atoms of carbon which each contains:—

1	Menisispermina .	$C^{18} H^{12} Az O^{2}$
2	Cinchonina . .	$C^{20} H^{12} Az O^{1\frac{1}{2}}$
3	Quinina . . .	$C^{20} H^{12} Az O^{2}$
4	Arecina . . .	$C^{20} H^{12} Az O^{3}$
5	Salicin . . .	$C^{4} H^{3} O^{2}$
6	Sabdillina . .	$C^{20} H^{3} Az O^{5}$
7	Thebaina . .	$C^{25} H^{14} Az O^{4}$
8	Delphina . .	$C^{27} H^{18} Az O^{2\frac{1}{2}}$
9	Narceina . .	$C^{28} H^{20} Az O^{12}$
10	Codeina . .	$C^{32} H^{19} Az O^{5}$
11	Strychnina . .	$C^{30} H^{16} Az O^{4}$
12	Brucina . . .	$C^{32} H^{18} Az O^{7}$
13	Veratrina . .	$C^{34} H^{32} Az O^{6}$
14	Emetina . .	$C^{35} H^{25} Az O^{9}$
15	Solanina . .	$C^{28} H^{21} Az^{\frac{1}{2}} O^{3\frac{1}{2}}$

16 Narcotina	. .	C^{40} H^{20} Az O^{12}
17 Morphina	. .	C^{34} H^{18} Az O^{6}
18 Atropina	. .	C^{22} H^{15} Az O^{3}
19 Conicina	. .	C^{12} H^{14} Az O
20 Parillina	. .	C^{9} H^{8} O^{3}
21 Meconin	. .	C^{10} H^{5} O^{4}

It will be seen, that each of these alkalies contains an atom of azote, with the exception of solanina, which contains only half an atom, and parillina, which contains none. The two bodies terminating in *in* are not alkalies.

SECTION I.—OF MENISPERMINA.

The fruit of the *menispermum cocculus* (*cocculus suberosus* of Decandolle), a black berry about the size of a pea, which comes from the East Indies, was first examined by M. Boullay in 1811, who extracted from it a peculiar poisonous substance, to which he gave the name of picrotoxin,* an account of which has been given in a preceding Chapter of this volume. It was examined in 1825 by M. Casaseca, who concluded from his experiments that it was destitute of alkaline properties, and incapable of uniting with acids.† In 1833, the subject was resumed by Pelletier and Couerbe, who examined picrotoxin with great care, and showed that it possessed rather the properties of an acid than a base.‡ But these gentlemen detected two alkaloids in the *cocculus indicus*, to which they have given the names of *menispermina* and *paramenispermina*.

These alkalies were obtained from the covering of the seeds of *cocculus indicus* in the following manner:—The matter was reduced to a coarse powder, and digested in boiling alcohol as long as any thing soluble was taken up. The tinctures were filtered, and the alcohol drawn off by distillation, till the liquid was reduced to the consistence of an extract. This extract being digested in hot water, a brown-coloured liquid was obtained, which when mixed with ammonia, let fall a brown-coloured precipitate. The colour was in a good measure removed by treating it with water acidulated with acetic acid. This dilute acid dissolves the precipitate with the exception of a black matter, and a little phosphate of lime. The matter being again precipitated by ammonia, assumes the form of a greyish-yellow resin, which when left undisturbed at the bottom of the vessel soon assumed the form of a powder. Being dried, dissolved in alcohol, and left to spontaneous evaporation, it furnished three distinct substances. 1. A substance having a resinous appearance, and alkaline properties. This substance Pelletier and Couerbe denominate *yellow alkaline matter*, and consider it as similar to a substance found in the mother water of nux vomica, cinchona, opium, &c., after the extraction of strychnina, quinina, morphina, &c.

* Ann. de Chim. lxxx. 209. † Ann. de Chim. et de Phys. xxx. 307.
‡ Ibid. liv. 178.

2. The second substance is crystallized in fine prismatic needles. This is *menispermina.* 3. The third substance has the aspect of a buff-coloured mucilage. This is *paramenispermina.* These three substances may be separated from each other in the following manner :—Cold hydrous alcohol dissolves the yellow alkaline resin. Ether dissolves the menispermina, while absolute alcohol dissolves the paramenispermina, and deposits it in crystals.

Menispermina thus obtained is white and opaque, and has very much the external appearance of cyanodide of mercury. The crystals are four-sided prisms, terminated by four-sided pyramids. It is tasteless, and seems to have no marked action on the animal economy. At least, 6 grains taken into the stomach produced no sensible effect.

It melts when heated to 249°. When heated in a glass tube it is decomposed, and leaves a bulky charcoal. But if it be heated in a watch glass, so as to allow free access to the air, it leaves very little charcoal behind it.

It is insoluble in water. Alcohol and ether dissolve it cold, and still better when hot. When the solutions are concentrated, the menispermina is deposited in crystals.

Dilute acids dissolve it, and at the same time are neutralized. From these solutions the alkalies precipitate menispermina unaltered. Concentrated sulphuric acid while cold has little action on it; but when assisted by heat, dissolves it unaltered, as it is again precipitated by the addition of water and ammonia. Concentrated nitric acid has little action on menispermina while cold, but when assisted by heat it converts it into oxalic acid, and a yellow-coloured resinous-looking matter.

Sulphate of menispermina crystallizes in prismatic needles. It melts at 329°, and while liquid resembles wax. When the heat is increased, the menispermina becomes red, and is decomposed, while sulphuretted hydrogen gas is given off. The constituents of this salt, determined by the analysis of Pelletier and Couerbe, are

Sulphuric acid . . .	5
Menispermina . . .	56·81
Water	10·90

Pelletier and Couerbe consider this sulphate as a subsalt, composed of 4 atoms menispermina united to 1 atom sulphuric acid. If this opinion be well founded, the atomic weight of menispermina will be 14·25.

They subjected it to an ultimate analysis, and found its constituents as follows :—

Carbon	71·80 or 18 atoms	= 13·5	or per cent.	72
Hydrogen	8·00 or 12 atoms	= 1·5	— —	8
Azote	9·57 or 1 atom	= 1·75	— —	9·33
Oxygen	10·53 or 2 atoms	= 2·00	— —	10·67
	99·90	18·75		100·00

This analysis makes the atomic weight 18·75, which does not cor-

respond very well with the number 14·25, derived from the analysis of sulphate of menispermina. Perhaps, therefore, it would be better (especially as very few tetrasalts are known) to consider the sulphate of menispermina, analyzed by Pelletier and Couerbe, as a disulphate, which would make the atomic weight of menispermina 28·4, and to consider the constituents to be

27	atoms carbon	= 20·25	or per cent.		72
18	atoms hydrogen	= 2·25	—	—	8
1½	atom azote	= 2·625	—	—	9·33
3	atoms oxygen	= 3·000	—	—	10·67
		28·125			100

Here the ratios remain as before, but the number of atoms is increased by one-half.

Paramenispermina is solid at the ordinary temperature of the atmosphere. Its crystals are oblique four-sided prisms, generally arranged in stars. It is not easily decomposed on account of its volatility. When heated in a glass tube it sublimes unaltered. If it be heated in a watch-glass, it begins to be volatilized in a white smoke before it has been completely melted. If the glass be withdrawn from the flame we see this smoke fall down again like snow, and the globule of melted paramenispermina becomes enveloped in a brilliant crystalline crust. The fusing point may be fixed at 482°, and the point of volatilization is nearly the same.

It is not sensibly soluble in water, and ether dissolves it in very minute quantity. Its true solvent is absolute alcohol, and the solution is promoted by heat.

The mineral acids have very little action on paramenispermina at the temperature of 57°. When heat is applied they decompose it. Dilute acids dissolve it; but without being neutralized or altering their form. Of course paramenispermina does not possess alkalkine properties, nor does it form salts. Yet its constituents, according to the analysis of Pelletier and Couerbe, are exactly the same as those of menispermina.

SECTION II.—OF CINCHONINA.

This alkali was detected by Pelletier and Caventou, in 1820, in the grey Peruvian bark, which is considered as the bark of the *cinchona nitida*, or the *cinchona condaminea*,* and is not much esteemed for its medical properties. But there is reason to suspect that the *cinchona lancifolia* of Loxa, the most celebrated of all the varieties of cinchona, contains the same principle.

Pelletier and Caventou extracted it from this bark by the follow- process :—

2 kilogrammes (4⅖ lbs. avoirdupois) of grey bark in powder were digested in 6 kilogrammes (13⅕ lb.) of alcohol. This treatment was repeated four times. The alcoholic tinctures were all united,

* Ann. de Chim. et de Phys. xv. 289.

and the alcohol was distilled off after the addition of 2 litres (122 cubic inches) of water. The residual liquid was filtered, and it left on the filter a reddish matter apparently resinous, which was washed with water containing a little potash till the liquid passed without colour. The matter remaining on the filter, after being well washed with distilled water is greenish-white, very fusible, soluble in alcohol, and capable of crystallizing. It was *cinchonina*, not quite freed from foreign matter.

To purify it, they dissolved it in very dilute muriatic acid. The weak acid dissolved the cinchonina, but left undissolved the greater part of the matter with which it was mixed. The solution, which had a golden-yellow colour, was digested with magnesia, assisted by a gentle heat. The magnesia, which was employed in excess, decomposed the muriate of cinchonina and formed a precipitate consisting of the cinchonina mixed with the excess of magnesia. It was collected on a filter, and washed with cold water till that liquid passed colourless. The precipitate was now dried on the water-bath, and treated thrice successively with boiling alcohol, which dissolved the cinchonina. The solutions, when evaporated, deposited crystals of a dirty-white colour. But, by a second solution and crystallization, they were obtained quite white and brilliant.

It crystallizes in delicate prismatic needles, or in white hairy translucent tufts. It requires 2500 times its weight of boiling water to dissolve it, and, on cooling, the liquid in general becomes opaline; showing that cinchonina is more soluble in boiling than in cold water.

It has a peculiar bitter taste, which is not much perceived at first on account of its very little solubility. When rendered soluble by being united with acids, its taste is very bitter, styptic, and permanent, similar to a strong decoction of cinchona bark, only less astringent.

It is not altered by exposure to the air. When heated in a somewhat large-sized tube the dry cinchonina does not melt, but furnishes a crystalline sublimate; whether this sublimate be the unaltered cinchonina has not been determined.

It is very soluble in alcohol, especially when assisted by heat. A saturated alcoholic solution at a boiling temperature crystallizes on cooling. The alcoholic solution is very bitter.

It is soluble in ether, but less so than in alcohol, especially while cold. It is slightly soluble in fixed oils, and still more soluble in volatile oils, at least in oil of turpentine.

Pelletier formed an iodide of cinchonina by the following process: Cinchonina was triturated with half its weight of iodine, and then digested in alcohol of 0·837. When the solution is left to spontaneous evaporation the iodide is deposited in safron-coloured plates. Towards the end of the evaporation some hydriodate of cinchonina is deposited.

The colour of the iodide is a deep-yellow. Its taste is slightly bitter. When heated to 77° it becomes soft, and melts at 176°. It

is insoluble in cold water, and very little soluble in boiling water. It is soluble in alcohol and ether. When acted on alternately by acids and alkalies it is decomposed. According to the analysis of Pelletier, it is composed of

1 atom iodine . . .	15·75
2 atoms cinchonina . .	38·5
	54·25*

Cinchonina does not combine with combustible bodies, nor with those oxides that are destitute of acid properties.

It was analyzed by Pelletier and Dumas, and by Liebig, and by Henry and Plisson. The following table shows the results :—

	P. and D.†	Liebig.‡	Henry and Plisson.§
Carbon	76·97	76·36	78·88
Hydrogen	6·22	7·37	8·876
Azote	9·02	8·87	9·3522
Oxygen	7·97	7·40	2·8918
	100·18	100	100·0000

Liebig found that 630 parts of dry cinchonina absorbed 143 parts of muriatic acid. Hence the muriate of cinchonina is composed of

Muriatic acid . . .	4·625
Cinchonina	20·36

This makes the atomic weight of cinchonina 20·36.

But the ultimate analysis of Liebig, which was made with very great care, leads to the conclusion that the atomic weight is 19·25, and the constituents as follows :—

20 atoms carbon	= 15	or per cent.	77·93
12 atoms hydrogen	= 1·5	— —	7·79
1 atom azote	= 1·75	— —	9·09
1 atom oxygen	= 1·00	— —	5·19
	19·25		100·00

Liebig's analysis would agree much better with the supposition that the integrant particle of cinchonina contains $1\frac{1}{2}$ atom oxygen. It would then stand thus,

20 atoms carbon	= 15	or per cent.	76
12 atoms hydrogen	= 1·5	— —	7·6
1 atom azote	= 1·75	— —	8·8
$1\frac{1}{2}$ atom oxygen	= 1·50	— —	7·6
	19·75		100·0

These numbers agree almost exactly with the result of Liebig's analysis.

The salts of cinchonina have a bitter taste They are precipitated by oxalates, tartrates and gallates, and by the infusion of nut-

* Ann. de Chim. et de Phys. lxiii. 181. † Ibid. xxiv. 176.
‡ Poggendorf's Annalen, xxi. 24. § Jour. de Pharmacie, xvii. 453.

galls. Cinchonina combines in two proportions with acids, forming neutral salts and disalts, or salts composed of 2 atoms base united to 1 atom acid.

1. *Muriate of cinchonina.* The composition of the neutral muriate formed by exposing dry cinchonina to the action of muriatic acid gas has been already given.

When we dissolve cinchonina in muriatic acid we always obtain a dimuriate, which crystallizes in needles. It is very soluble in water. It dissolves also in alcohol but scarcely in ether. Its composition, according to the analysis of Pelletier and Caventou, is

Muriatic acid . . .	4·625
Cinchonina . . .	39·42

This is obviously 2 atoms of cinchonina to 1 atom of muriatic acid.

2. *Hydriodate of cinchonina.* This salt is but little soluble in water; but if we saturate boiling water with it we may obtain the salt in crystals by allowing the solution to cool. The crystals are transparent needles with a pearly lustre. With corrosive sublimate and with cyanodide of mercury it forms curdy precipitates, which, according to Caillot, are double salts. It is more soluble in hot water, and crystallizes during the cooling of the solution. At first it seems tasteless; but it leaves a bitter and metallic impression.*

3. *Sulphate of cinchonina.* When sulphuric acid is saturated with cinchonina, we obtain, as *Baup* has shown, a *disulphate*, which crystallizes in short oblique prisms terminated by bihedral summits.

It dissolves in 6 parts of alcohol of the specific gravity 0·85, and in 11 parts of absolute alcohol. It is soluble in 54 times its weight of cold water. Its constituents are

1 atom sulphuric acid . .	5
2 atoms cinchonina . . .	40·5
4 atoms water . . .	4·5
	50

When dried in a temperature of 248°, it loses all its water of crystallization.

If we add sulphuric acid to the solution of disulphate of cinchonina and evaporate till a pellicle forms on the surface, we obtain, after allowing the liquid to remain sometime at rest in a cool place, crystals of *neutral sulphate of cinchonina.*

This salt is colourless, does not undergo any alteration from exposure to the air, except becoming slightly opaque in a dry atmosphere. The crystals are octahedrons, consisting of two four-sided pyramids with rhomboidal bases. They effloresce when slightly heated. It is soluble in about half its weight of water at the temperature of 55°, in rather less than its weight of alcohol of the sp. gravity 0·85, and in its own weight of absolute alcohol at the same temperature. Its constituents are

* Pelletier, Ann. de Chim. et de Phys. lxiii. 183.

1 atom sulphuric acid . .	5
1 atom cinchonina . . .	20·25
8 atoms water . . .	9
	34·25

4. *Nitrate of cinchonina.* This salt must be prepared by saturating very dilute nitric acid with cinchonina. When its solution is pretty concentrated, whether it be hot or cold, a portion of nitrate of cinchonina separates in globules having an oily appearance. If these globules be covered with water they are converted in two or three days into groups of crystals. This curious character distinguishes cinchonina and quinina (which possesses it also) from all the other vegetable alkaloids.

5. *Carbonate of cinchonina.* Cinchonina absorbs carbonic acid from the atmosphere. The carbonate may be obtained by precipitating a soluble salt of cinchonina by an alkaline carbonate.

6. *Phosphate of cinchonina.* This salt is very soluble, and only forms the rudiments of crystals, or assumes the form of transparent plates.

7. *Arseniate of cinchonina.* This salt is very soluble in water and crystallizes with difficulty.

8. *Chlorate of cinchonina.* This salt may be obtained by dissolving cinchonina in chloric acid. It crystallizes in white tufts. When heated it melts, and if the heat be increased it is decomposed with an explosion. It is less fusible and more easily decomposed than chlorate of quinina. According to Serullas this salt is a dichlorate.

9. *Iodate of cinchonina.* Obtained like the last. It crystallizes in very fine needles in tufts. According to Serullas it is a diodate of cinchonina. It is composed of

1 atom iodic acid . . .	20·75
2 atoms cinchonina . .	38·5
	59·25*

10. *Acetate of cinchonina.* Acetic acid dissolves cinchonina; but the liquid remains acid, whatever quantity of cinchonina we employ. When concentrated it deposits small translucent scales. When these scales are washed they are no longer acid, and are little soluble in water. When we evaporate to dryness we obtain a gummy mass, which water decomposes into binacetate, which dissolves, and diacetate, which remains undissolved.

11. *Tartrate of cinchonina.* This salt is similar to the oxalate, but is more soluble in water.

12. *Oxalate of cinchonina.* It precipitates in the form of a white powder, little soluble in water when an oxalate is mixed with a salt of cinchonina. By adding an excess of acid it becomes soluble, forming a binoxalate.

13. *Gallate of cinchonina.* Gallic acid throws down a precipitate

* Pelletier, Ann. de Chim. et de Phys. lxiii. 183.

from a solution of a cinchonina salt, which is scarcely soluble in cold water. But it dissolves when the liquid is heated. On cooling, the liquid becomes milky, but, after some hours, it becomes again transparent, and the gallate of cinchonina is deposited in small granular translucent crystals.

14. *Tannate of cinchonina* is composed, according to M. O. Henry, of

Tannin . . .	72·84 or 54·30
Cinchonina . .	27·16 or 20·25
	100·00*

It is therefore a tertannate.

15. *Kinate of cinchonina.* When the solution of this salt is concentrated to the state of a syrup and set aside for a few days it deposits silky needle-form crystals, which are very soluble in water. It is composed of

Kinic acid	11·94
Cinchonina	19·75
	31·69†

It is therefore a dikinate.

SECTION III.—OF QUININA.

Some steps toward the discovery of this principle, certainly one of the most important of all the alkalies, was made by Vauquelin,‡ and by Gomes, in 1811;§ but it was Pelletier and Caventou who, in 1820, pointed out its alkaline character, and showed how it may be obtained in a separate state.‖ Since that period sulphate of quinina has come into general use as a medicine, and has almost superseded the administration of bark. Quinina may be extracted from the *yellow bark*, usually considered as the bark of the *cinchona cardifolia*, by the following process:—

Let the yellow bark be coarsely pulverized, and boiled in eight times its weight of water, containing five per cent. of sulphuric acid. Let this boiling be repeated, with an additional dose of acidulated water. Filter, and squeeze out the liquid portion from the undissolved bark. Mix the liquid thus obtained with unslacked lime, amounting to a fourth of the weight of the yellow bark employed. Agitate well, and as soon as the liquid begins to exhibit alkaline characters, let it be passed through a filter. The lime remaining on the filter is to be washed with a little cold water, exposed to pressure, and then dried. It is then to be boiled three times successively, in different portions of alcohol, of the specific gravity 0·836. Mix the filtered alcoholic solutions with a little water, and distil off the spirit. The water remaining contains, mixed with it,

* Jour. de Pharmacie, xxi. 221.
† Henry and Plisson, Jour. de Pharmacie, xv. 406. ‡ Ann. de Chim. lix. 113.
§ Edinr. Med. and Surg. Journal, 1811, p. 420.
‖ Ann. de Chim. et de Phys. xv. 345.

the quinina, but not free from colouring matter. Let it be dissolved in an acid, mixed with ivory black, and digested. When the filtered solution is now mixed with an alkali, the quinina is precipitated in a state of purity.

As sulphate of quinina is prepared on a large scale for the use of medical men, it is more convenient to obtain quinina from that salt than to prepare it from the yellow bark. Nothing more is necessary than to dissolve the sulphate in water, and to mix the solution with a dilute solution of ammonia. The quinina falls in white flocks. It generally becomes a little coloured during the process of drying.

Quinina crystallizes with difficulty, and was long thought incapable of assuming a regular form. Pelletier first showed that when alcohol of 0·815 is saturated with it, and the solution set aside in a cool place, the quinina, by spontaneous evaporation, is deposited in silky tufts, consisting of minute needles. If we dissolve it in hot alcohol, and add a small quantity of ammonia to the liquid, and then set it aside to allow the liquid to cool, crystals of quinina are deposited in fine needles.

The crystallized quinina is in the state of a hydrate. When it is exposed to heat it softens first, and then falls down in the state of a white powder. When heated to the temperature of 302°, or a few degrees higher, it melts, and loses the whole of its water. When suddenly cooled, while in fusion, it becomes yellow, translucent, and brittle, like rosin. When slowly cooled it assumes a fibrous texture, and becomes opaque.

When rubbed it becomes negatively electric.

When quinina, freed from water, is put into that liquid, it gradually swells, and absorbs again all the water which it had lost.

Its taste is intensely bitter, similar to that of yellow bark itself. The taste is much stronger than that of cinchonina.

It is soluble in 200 times its weight of boiling water. It is abundantly soluble in alcohol, and is usually deposited from it in a soft viscid mass, which becomes indurated in the air, and assumes the aspect of a resin. It is more soluble in ether than cinchonina is.

Iodide of quinina may be formed in the same way as iodide of cinchonina, and the two iodides resemble each other so closely, that it is difficult to distinguish them. This iodide, according to the analysis of Pelletier, is composed of

1 atom iodine . . .	15·75
2 atoms quinina . . .	40·5
	56·25*

We have four analyses of quinina, one by Pelletier and Caventou, one by Pelletier and Dumas,† one by Liebig,‡ and one by Henry and Plisson.§

* Ann. de Chim. et de Phys. lxiii. 184.
† Ibid. xxiv. 169.
‡ Poggendorf's Annalen, xxi. 25.
§ Jour. de Pharmacie, xvii. 453.

	P. & C.	P. & Dumas.	Liebig.	Henry & Plisson.
Carbon .	75	75·02	74·40	74·552
Hydrogen	6·25	6·66	7·61	8·4322
Azote .	8·75	8·45	8·11	8·2946
Oxygen .	10	10·43	9·88	8·7212
	100	100·56	100·00	100·0000

To determine the atomic weight of quinina, Leibig analyzed the sulphate, and found it composed of

Quinina . .	85·83	or 42·915
Sulphuric acid .	10·00	or 5
Water . . .	4·17	or 2·085
	100·00*	

This salt being a disulphate, it follows, from the above analysis, that the atom of quinina weighs 21·4575.

The atomic constituents which would correspond best with Liebig's analysis, are the very same as we have given for the constituents of cinchonina; namely,

20 atoms carbon	= 15	or per cent.	74·08
12 atoms hydrogen	= 1·5	— —	7·40
1 atom azote	= 1·75	— —	8·64
2 atoms oxygen	= 2·00	— —	9·88
	20·25		100·88

But the atomic weight derived from the analysis of disulphate of quinina would indicate 21·25 at least. I am disposed (considering the difficulty of an exact analysis of sulphate of quinina) to adopt 20·25 for the atomic weight of quinina, and to conclude that cinchonina agrees with it exactly in composition, but contains only one atom and a half of oxygen. This would reduce its atomic weight to 19·75.

The salts of quinina are distinguished by a strong bitter taste, similar to that of yellow bark, and those that are in crystals have a pearly lustre. Most of them are soluble in water, and several of them soluble in alcohol and in ether. These solutions are precipitated by oxalic, tartaric, and gallic acids, and also by the infusion of nutgalls.

1. *Muriate of quinina.* This salt crystallizes in needles, distinguished by a pearly lustre. It is but little soluble in water. It would appear, from the experiments of Liebig, compared with those of Pelletier and Caventou, that there are two distinct species of this salt. According to Liebig, 100 parts of quinina absorb 24·1 parts of muriatic acid. But there was an excess of the acid, which had lodged itself in the pores of the quinina. Allowing for this excess, the salt is obviously a compound of

* Poggendorf's Annalen, xxi. 26.

1 atom muriatic acid . .	4·625
1 atom quinina . . .	20·25
	24·875

The muriate of quinina formed by Pelletier and Caventou contained only 7 per cent. of the muriatic acid. Hence it is a compound of

Muriatic acid . . .	4·625
Quinina	61·44

Now, $\frac{61{\cdot}44}{3} = 20{\cdot}48$. So that the salt of Pelletier and Caventou contained 3 atoms quinina, united to one atom muriatic acid.

2. *Hydriodate of quinina.* This salt is formed along with iodate, when a mixture of quinina and iodine is digested in hot water. Both salts precipitate, when the liquid cools, in the form of a white powder.

3. *Sulphate of quinina.* The powerfully febrifuge properties of this salt has introduced it into general use as a medicine in every part of the civilized world. On this account it has become an important article of manufacture, especially in France, where the cheapness of the alcohol, compared with its price in this country, enables the manufacturers to produce it at a much lower rate than could be done in this country. The annual produce in Paris, where it is chiefly made, exceeds 120,000 ounces per annum. The process usually followed is that of M. Henri, junior, with some slight modifications. It is as follows:—

The yellow bark is reduced to powder, and boiled with 8 or 10 times its weight of water, acidulated with 12 per cent. of sulphuric, or 25 per cent. of muriatic acid. The boiling is continued for at least an hour, and the liquid is then strained through a cloth. The residual bark is boiled three or four times successively with new portions of acidulous water, till the liquids cease to acquire any taste.

When these decoctions (which are all mixed together) are cold, they are mixed with milk of lime, by small portions at a time, taking care to agitate without intermission, to promote the action of that base upon the acidulous liquor. Lime must be added, slightly in excess, which is determined by ascertaining when the liquid acts like an alkali on vegetable colours. This excess forms, with the colouring matters of the bark, an insoluble lake. Accordingly, when enough of lime has been added, it will be found that the liquid has lost its red colour, and become deep grey.

The lime will occasion a considerable deposit. When it has separated from the liquid portion it is poured upon a cloth, and after the liquid part has run off, the residual matter is subjected to a graduated pressure. The liquids must be set aside, because they gradually let fall a new deposit.

The precipitated matter, thus freed from water, is allowed to dry, and then digested in alcohol, of the specific gravity 0·847, in

order to dissolve the quinina. The digestion must be repeated, with fresh portions of alcohol, over the water-bath, till all the quinina is dissolved.

The alcoholic liquids, containing the quinina, are now subjected to distillation, and about three-fourths of the alcohol employed is recovered. To the residual liquid sulphuric acid is added till it reddens litmus paper. The liquid is evaporated to the requisite quantity, and then set aside. The sulphate of quinina is gradually deposited in crystals.

The great expense of this process is the quantity of alcohol consumed. M. Pelletier, some years ago, took out a patent for a new process, in which oil of turpentine is substituted for alcohol. The dry matter, from the action of lime on the acidulous decoctions of the bark, is digested in oil of turpentine, which dissolves the quinina. When the oil, containing the quinina, is agitated with water acidulated with sulphuric acid, the quinina unites with the acid, and the salt is held in solution in the water. The oil of turpentine swims on the surface, and may be decanted off. The sulphate is obtained in the usual way from this liquid by concentration.

When this patent process is followed, it is said that the produce from the bark is about $\frac{1}{20}$th less than by Henri's process. This more than counterbalances the saving of alcohol, in consequence of which, Pelletier's process is seldom employed. Good yellow bark yields about $\frac{1}{34}$th part of its weight of sulphate of quinina, or from 34 pounds of the bark, one pound of sulphate of quinina may be extracted by Henri's process.

There are two sulphates of quinina: the *disulphate*, and the *neutral sulphate;* the former is the one commonly employed in medicine.

Disulphate of quinina effloresces when exposed to the air. It is soluble in 740 times its weight of water at the temperature of 55°, and in thirty times its weight of boiling water. It dissolves in eighty times its weight of alcohol of the specific gravity 0·85, at the ordinary temperature of the atmosphere. It crystallizes in tufts, composed of fine needles, which are slightly flexible, and have a pearly lustre. When heated it readily melts, and assumes the appearance of liquid wax. At a still higher temperature it assumes a fine red colour, and at last burns all away, without leaving any residue.

From the analysis of this salt, by Liebig, stated in a preceding page, it is evident that it is a compound of

2 atoms quinina . . .	40·5
1 atom sulphuric acid . .	5
2 atoms water . . .	2·25
	47·75*

* The analysis of this salt by Robiquet comes exceedingly near these theoretic numbers. See Ann. de Chim. et de Phys. xvii. 320.

This, however, is the constitution of the salt after it has effloresced. The crystals consist of

2 atoms quinina . . .	40·5
1 atom sulphuric acid . .	5
8 atoms water . . .	9
	54·5

Neutral sulphate of quinina was first made and analyzed by Robiquet.* It may be formed by adding a little sulphuric acid to the solution of the disulphate, and crystallizing the solution. The crystals are rectangular prisms, with rectangular or square bases. At the temperature of 55°, it dissolves in eleven times its weight of water; while at 72°, it requires only eight times its weight of that liquid to dissolve it. At 212° it is soluble in its water of crystallization. It is much more soluble in hot than in cold alcohol, whatever the specific gravity of the alcohol may be. When crystallized in alcohol the crystals fall to powder on exposure to the air. It reddens vegetable blues, though its taste is not perceptibly acid, but bitter. Its constituents, from a comparison of the analyses of Robiquet and Baup, appear to be

1 atom quinina . . .	20·25
1 atom sulphuric acid . .	5
8 atoms water . . .	9
	34·25

The high price of sulphate of quinina, and its great importance in medicine, have induced fraudulent dealers sometimes to adulterate it by a mixture of foreign matter. Sulphate of lime in needles, boracic acid, margaric acid, and sugar, are the ingredients most commonly employed for that purpose. The presence of sulphate of lime, or boracic acid, is easily ascertained by incinerating a portion of the suspected salt. The sulphate of lime or boracic acid will remain behind. Margaric acid may be separated by means of weak muriatic acid, which dissolves sulphate of quinina, but leaves the margaric acid. To detect sugar, we may dissolve a little of the suspected salt in water, and throw down the sulphuric acid by means of barytes water. The quinina will fall at the same time, and a current of carbonic acid gas will throw down any excess of barytes which may have been added, leaving nothing but the sugar, easily recognizable by its taste.

4. *Nitrate of quinina.* Quinina combines readily with nitric acid, and when the solution is concentrated, the salt separates under the form of an oleaginous liquid, which gradually assumes a crystallized form. The crystals are rectangular prisms with inclined bases.

5. *Phosphate of quinina.* This salt crystallizes readily in small white needles, having a pearly lustre. It is soluble in alcohol, and also in water.

* Ann. de Chim. et de Phys. xvii. 317.

6. *Arseniate of quinina.* This salt resembles the phosphate very closely, excepting that its lustre is less pearly. As the arseniate of cinchonina does not crystallize, we can easily distinguish between these two alkaloids by combining them with arsenic acid.

7. *Chlorate of quinina.* It is obtained by saturating dilute chloric acid with quinina, and concentrating the solution. Its crystals are very fine needles, united in tufts. When heated, it melts into a colourless liquid, which, on cooling, solidifies into a transparent varnish. If we increase the heat, the salt suddenly explodes, and is decomposed.

8. *Iodate of quinina.* Obtained in the same way as the preceding salt. It crystallizes in silky needles.

9. *Acetate of quinina.* This salt is easily distinguished from the *acetate of cinchonina.* The latter salt, with an excess of acid, does not crystallize; whereas the acetate of quinina, with an excess of acid, crystallizes readily. When the liquid acetate is concentrated, it assumes, all at once, the form of a solid mass, composed of long needles, having a pearly or silky lustre. By a slow evaporation the flat needles group themselves into stars. This salt is so little soluble in cold water, that when it is coloured it may be rendered white, by washing it in cold water. It is much more soluble in hot water. A saturated solution in boiling water becomes solid on cooling.

10. *Tartrate of quinina.* Similar to the oxalate, but more soluble in water.

11. *Oxalate of quinina.* This salt may be obtained, by mixing a solution of oxalate of ammonia with any soluble salt of quinina. It precipitates in the state of a white powder. It is but little soluble in cold water, but boiling water dissolves it better. A saturated boiling hot solution assumes, on cooling, the form of a pearly mass, composed of needles.

The neutral oxalate is very soluble in alcohol, and by allowing a saturated boiling-hot alcoholic solution to cool, the salt is deposited in white needles.

12. *Gallate of quinina.* This salt precipitates in the form of a white powder, when a gallate is mixed with a soluble salt of quinina. The gallate of quinina dissolves in boiling water. When the liquid cools it becomes milky, and an opaque powder is deposited. Gallate of quinina is soluble in alcohol, and in an excess of acid.

13. *Bitannate of quinina.* The infusion and tincture of gall nuts, throws down quinina from its solutions. The precipitate is scarcely soluble in water, but dissolves in acetic acid. It is composed, according to O. Henry, of

Tannin . . .	71·48 or 50·75
Quinina . . .	28·52 or 20·25
	100·00*

* Jour. de Pharmacie, xxi. 221.

This is rather a tertannate than a bitannate; for 3 atoms of tannin weigh 49·875.

14. *Kinate of quinina.* This salt is very soluble in water, and crystallizes most readily when the solution has an excess of acid. The crystals are needles, or mushroom-shaped tubercles. Taste bitter. Composed of

Kinic acid	10·42
Quinina	20·25

It is, therefore, a dikinate.*

15. *Hydroferrocyanate of quinina.* Hydrocyanate of quinina has been found a more powerful febrifuge than sulphate, but being kept in a liquid state, it is liable to undergo decomposition. This induced M. Bertozzi, apothecary to the hospital of Cremona, to prepare hydroferrocyanate of quinina.† The process was as follows:—

One part of sulphate of quinina is reduced to an impalpable powder, and mixed with $1\frac{1}{2}$ parts of common prussiate of potash, previously dissolved in six or seven times its weight of water. The two substances being well agitated together, are put into a phial and gradually heated, under repeated agitation, to the boiling point. A greenish-yellow matter precipitates to the bottom, having an oily consistency. Decant off the liquid, wash the deposit with cold water, and dissolve it in alcohol. Filter, and evaporate. The salt is deposited in confused crystals.

It has a greenish-yellow colour, and a very bitter taste. It dissolves in cold alcohol, but much better in boiling alcohol, and is precipitated by water. It was found an excellent febrifuge, chiefly in those cases where sulphate of quinina failed to produce a cure.

SECTION IV.—OF ARICINA.

This alkali was accidentally discovered in 1829, by MM. Pelletier and Cariol, in the following manner:—A dispute took place between two Bourdeaux merchants, respecting a quantity of bark from Arica, in Peru, which had been sent to Europe as the bark of cinchona. It resembled the yellow bark exactly in its appearance, but it was alleged that no quinina could be obtained from it. A quantity of it was sent to Pelletier, in order to subject it to a chemical examination. He and M. Cariol, who, at that time, had the charge of his laboratory, subjected it to the process described in the last Section, for extracting quinina from yellow bark. But, instead of quinina or cinchonina, they obtained a salifiable base possessed of quite different properties. To this base they gave the name of *aricina*, from the place whence it came. The name of the tree which yields this bark (employed in South America to adulterate cinchona bark) is not known. Pelletier and Cariol drew up an account of this new alkaloid, which was read to the *Academy of Medicine* in Paris, and published in the *Journal de Pharmacie*.‡

* Henry and Plisson, Jour. de Pharmacie, xv. 405.
† Jour. de Pharmacie, xix. 45. ‡ Vol. xv. p. 575.

Aricina is white, and crystallizable. It has considerable resemblance to cinchonina, but differs from that base in many of its properties.

It is insoluble in water. Hence it seems at first to have no taste, but when kept for some time in the mouth, it leaves a sharp and hot impression. When dissolved in an acid, its taste becomes intensely bitter.

When heated it melts, like quinina, at a temperature lower than that at which it undergoes decomposition; but it cannot be volatilized like cinchonina.

Like the other alkaloids, it saturates acids, and forms with them salts.

The *sulphate of aricina* is not crystallizable from its aqueous solution. When we dissolve the salt in boiling water, it assumes, on cooling, the form of a white tremulous jelly, which, when left exposed to the atmosphere, assumes the appearance of horn. This matter, when digested in boiling water, is again converted into a jelly. When dissolved in boiling alcohol it crystallizes in silky needles, having much of the aspect of sulphate of quinina. When we add to the gelatinous sulphate a few drops of sulphuric acid, a bisulphate is formed, which crystallizes in flat needles.

When aricina is dissolved in concentrated nitric acid, it assumes a very deep-green colour. If the acid be weaker the green colour is lighter, and when it is very dilute it dissolves the aricina without communicating any colour whatever. In this last case, a simple nitrate of aricina is formed; but when the aricina assumes a green colour its nature is altered.

This alkaloid was subjected to an ultimate analysis by Pelletier,* who obtained the following result:—

Carbon	71 or 20 atoms	= 15	or per cent.	70·59
Hydrogen	7 or 12 atoms	= 1·5	— —	7·06
Azote	8 or 1 atom	= 1·75	— —	8·24
Oxygen	14 or 3 atoms	= 3·00	— —	14·11
	100	21·25		100·00

If the atomic weight of aricina be 21·25, and its constituents as now stated, it is obvious that a very simple relation exists between cinchonina and aricina. The atoms of carbon, hydrogen, and azote, are the same in all: the only difference in their constitution lies in the proportion of oxygen, which is $1\frac{1}{2}$ atom in cinchonina, 2 atoms in quinina, and 3 atoms in aricina. This will become more evident, if we represent the atomic constitution of these bodies by symbols:

Cinchonina .	$(C^{20}\ H^{12}\ Az) + O^{1\frac{1}{2}}$
Quinina . .	$(C^{20}\ H^{12}\ Az) + O^{2}$
Aricina . .	$(C^{20}\ H^{12}\ Az) + O^{3}$

* Ann. de Chim. et de Phys. li. 186.

SECTION V.—OF SALICIN.

Though this substance does not possess alkaline properties, I am induced to place it here, in consequence of the analogy which it bears to the alkalies from the different varieties of cinchona.

It appears to have been discovered by M. Buchner in 1828.* It was detected in 1830, by M. Leroux, in the bark of the *salix helix*.† It may be obtained by the following process:—Boil the powdered bark with water till a strong decoction is obtained. Add to this decoction slacked lime till all the tannin is precipitated in the state of ditannate of lime. Then filter and concentrate the liquid to the consistence of a syrup, or we may precipitate the tannin by the white of eggs. Add alcohol, which will precipitate the gum. If we now concentrate the liquid it deposits *salicin*, which may be washed in a little cold water. By mixing the brown-coloured mother water with the diacetate of lead, we may obtain from it another portion of salicin. Dissolve all the salicin thus obtained in boiling water, and digest the solution with ivory black. Filter the boiling solution, and allow it to cool. It deposits pure colourless crystals of salicin.

Salicin thus obtained has the form of small white scales, which, under the microscope, appear to be rectangular tables with bevelled edges. Its taste is very bitter, and it has something of the aromatic flavour of the willow bark.

One hundred parts of water at the temperature of 67 , dissolve 5·6 parts of it. Hot water is a much better solvent, and boiling water dissolves it in any proportion whatever. It is soluble also in alcohol; but ether and oil of turpentine do not take up any sensible quantity of it. Concentrated sulphuric acid poured upon salicin gives it a beautiful red colour, very similar to that of bichromate of potash. This property is not confined to salicin in a state of purity; but holds in solutions containing no more than $\frac{1}{600}$th of their weight of this principle. Hence it may be employed to ascertain whether any bark contains salicin. It dissolves in muriatic and nitric acids, without becoming coloured. The solutions of salicin are not precipitated by nutgalls, gelatin, acetate, or diacetate of lead, alum, or tartar emetic. When boiled in excess with lime-water, no combination takes place; nor is it capable of dissolving oxide of lead. When heated a few degrees above the temperature of boiling water it melts, and, on cooling, assumes a crystalline form. When thus treated it loses no water; but if the heat be raised it assumes a lemon-yellow colour, and becomes brittle like resin.‡

It does not combine with acids, or possess alkaline properties.

* Jour. de Pharm. xvi. 242.

† Ann. de Chim. et de Phys. xliii. 440. See also Hoff, Jour. de Pharmacie, xvii. 169.

‡ Pelouze and Jules Gay-Lussac, Ann. de Chim. et de Phys. xliv. 220.

Its constituents, determined by the analysis of Pelouze and J. Gay-Lussac, are :—

Carbon	55·49
Hydrogen	6·38
Oxygen	38·13
	100·00*

As we do not know the atomic weight of salicin, we cannot deduce from this analysis the number of atoms of which it is composed. But C^4 H^3 O^2 gives an approximation of the smallest number of atoms which correspond with the above analysis. And $C^{11\frac{1}{2}}$ H^8 O^6 comes still nearer to it. The first would give 6·375 for the atomic weight, and the last, 15·625.

According to Herberger, the salicin of Leroux is a salt composed of a peculiar acid, combined with the true salicin, which possesses alkaline properties. It may be obtained by dissolving ordinary salicin in oxalic acid, and separating the oxalic acid by means of lime.

It crystallizes in prisms, restores the blue colour of reddened litmus paper, dissolves in alcohol and water, and combines with acids. He and Buchner formed the sulphate, nitrate, phosphate, acetate, tartrate, oxalic, and muriate of salicin. These salts are soluble in alcohol, but not in ether. They melt when heated, and most of them may be obtained in crystals. The acid of ordinary salicin is volatile, and may be distilled over.†

Braconnot found salicin in the bark of the *salix fissa*, *amygdalina* and *helix*. And M. Becker extracted it from the *salix helix*, and *salix purpurea*.‡ But he could not succeed in extracting any from the bark of the *salix alba*, *triandra*, *fragilis*, *capræa*, *viminalis*, *babylonica*, *bicolor*, *incana*, *daphnoides*, *russiliana*. But Hopff succeeded in obtaining it from the bark of the *salix viminalis*. And Peschier assures us that he got a small quantity from the bark of the *salix alba*, and a still greater proportion from that of the *salix incana*. According to Esenbeck, the *salix vitellina* yields it also. Dahlström found it in all the willows which are natives of Sweden.§ The bark of those branches that are from two to three years old contains most salicin. MM. Lorenzo and Morens appear to have obtained it from the *spartium monospermum*, a species of broom.‖

It appears, from the trials of M. Magendie, to have the property of stopping the progress of intermittent fevers : three doses of 6 grains each were found sufficient to cure the fever. It was tried by other medical men in the hospitals of Paris, all of whom confirmed the febrifuge virtues of this substance. It might therefore be introduced into medicine, as a substitute for sulphate of quinina, at least as far as the cure of intermittents is concerned.

* Pelouze and Jules Gay-Lussac, Ann. de Chim. et de Phys. xlviii. 111, and Ann. der Pharmacie, i. 43.

† Journal de Pharmacie, xvii. 225.

‡ Ann. der Pharmacie, iv. 33.

§ Berzelius, Traité de Chimie, vi. 235.

‖ Jour. de Pharmacie, xx. 127.

SECTION VI.—OF VERATRINA.

This alkaloid was discovered in 1819, by Pelletier and Caventou,* in the seeds of *veratrum album*, or *white hellebore*, and of the *veratrum sabadilla*, and probably it exists in the seeds of the other species of veratrum.

Pelletier and Caventou extracted *veratrina* from these seeds by the following process:—They were treated with sulphuric ether which dissolved a fatty matter, a volatile acid, and some other principles. The residual matter was digested in boiling alcohol, till every thing soluble was taken up. The brown-coloured tincture was filtered, and the alcohol distilled off, till the residue was brought to the consistence of an extract. Cold water dissolves the whole of this extract, except a small quantity of fatty matter, which is separated by the filter. The solution is concentrated, filtered again, and then mixed with acetate of lead, which throws down an abundant yellow precipitate, and renders the liquid nearly colourless. A current of sulphuretted hydrogen gas is passed through the filtered liquor, to throw down the excess of lead; the liquor is again filtered, concentrated, and then digested with magnesia. The precipitate thrown down by the magnesia being digested in boiling alcohol, and the alcoholic solution being distilled, a powder is obtained, at first yellowish, but which may be rendered white by solution in alcohol, and precipitation by water. This is veratrina; not, however, perfectly pure.

M. Couerbe extracted veratrina from the seeds of *veratrum sabadilla*, by the same process by which he extracted *delphina* from the seeds of delphinium staphysagria, and obtained it quite pure.†

Veratrina thus obtained, has the form of a yellow, brittle, and fusible resin. When in powder it appears white; but is far from being pure, for when dissolved in alcohol or a dilute acid the solution is yellow. To purify it, let it be dissolved in very dilute sulphuric acid, and let the solution be mixed with some drops of nitric acid. This occasions the subsidence of a copious black pitch-like precipitate. Decant off the clear liquid, and mix it with a dilute solution of potash. The veratrina falls, and when washed with cold water, and dissolved in boiling alcohol of the specific gravity 0·817, it is free from all inorganic matter. But it is still far from being pure, and contains at least three distinct substances, one of which is capable of crystallizing. When treated with boiling water a yellow solution is obtained, containing two of these substances. One of these, which is crystallizable, is deposited as the liquid cools in crystals having a tint of red. It is *sabadillina*. The mother water contains only traces of this substance; but it contains another matter, which separates as the liquid is concentrated under the form of drops of an oily consistency, which swim on the surface. By evaporating to dryness, we obtain this matter under the form of a

* Ann. de Chim. et de Phys. xiv. 69. † Ibid. lii. 368.

red resin, having a very acrid taste. Couerbe, who obtained it, gave it the name of *gumresin* of sabadillina.

The alkaline matter thus treated by water, is digested in ether, as long as any thing is dissolved. The solutions exposed to spontaneous evaporation, let fall a matter almost white and analogous to pitch, becoming brittle when slightly heated *in vacuo*. It is *veratrina* in a state of purity.

The residue, insoluble in water and ether, being digested in alcohol is dissolved, and this solution when evaporated, lets fall a peculiar resin which Couerbe has distinguished by the name of *resin of veratrina*.*

Veratrina thus purified, has the aspect of a resin. It is almost white, and cannot be crystallized. It is solid, friable, and fusible, at the temperature of about 240°. It restores the blue colour of reddened litmus paper. It combines with and saturates acids, and forms with them crystallizable salts. It is nearly insoluble in water—alcohol and ether are its best solvents.

It has no smell, but when drawn into the nostrils, even in a minute quantity, it produces violent and long-continued sneezing. Its taste is excessively acrid, without any mixture of bitterness. When taken internally, even in very minute quantity, it irritates the mucous membrane, and occasions frightful vomiting. A few grains of it occasion death.

M. Couerbe found muriate of veratrina composed of

Muriatic acid	4·625
Veratrina	34·74
And sulphate of sulphuric acid . .	5
Veratrina . . .	34·1

The mean of these gives the atomic weight 34·42.

From the analysis of veratrina by Couerbe, it appears to be composed of

Carbon	69·81 or 34 atoms	= 25·5	or per cent.	70·83
Hydrogen	7·64 or 22 atoms	= 2·75	— —	7·64
Azote	5·21 or 1 atom	= 1·75	— —	4·86
Oxygen	17·24 or 6 atoms	= 6·00	— —	16·67
	100·00†	36·00		100

Veratrina combines with acids, and forms salts which crystallize with difficulty. Indeed, none of them have been obtained in the state of crystals except the muriate and sulphate.

1. *Muriate of veratrina.* This salt may be formed by passing a current of muriatic acid gas over dry veratrina, or by dissolving the alkaloid in dilute muriatic acid, and leaving the solution to spontaneous evaporation. The salt is deposited in fine needles. It is very soluble in water and alcohol, and is easily decomposed by heat.

* What is called *veratrina* in the text, Couerbe names *veratrine*, and the resin just alluded to he distinguishes by the name of *veratrin*. We shall call it *resin of veratrina* to prevent ambiguity.

† Ann. de Chim. et de Phys. lii. 375.

2. *Sulphate of veratrina.* This salt may be obtained by saturating veratrina with water, acidulated with muriatic acid, till the whole becomes thick, and assumes a frothy appearance. Water is then added, and the whole is heated in order to obtain a complete solution. When the liquid is left to spontaneous evaporation, the salt crystallizes in fine needles, which when examined by the microscope appear to be four-sided prisms. It is very soluble in water. When heated it melts, loses its water of crystallization and is charred, while it emits vapours of sulphurous acid. According to Couerbe it contains two atoms of water.*

3. *Iodate of vertrina.* When dried it assumes the form of gum, without any appearance of crystallization.

4. *Chlorate of veratrina.* When evaporated it assumes the appearance of gum, with the smell of amber.

SECTION VII.—OF SABADILLINA.

This alkaloid was discovered by Couerbe, and obtained by him by the process described in the last Section. It has the form of small crystals radiating from a centre. The needles seem to be six-sided prisms.

Sabadillina is white, and has an intolerably acrid taste. Heat decomposes it without subliming it. It enters into fusion at 392°, and then assumes a resinous appearance and a brown colour. When the temperature is raised still higher it becomes black, and gives out a light smoke. It is then decomposed, leaving a considerable quantity of charcoal.

Water dissolves sabadillina readily when assisted by a gentle heat, and, on cooling, deposits it again in crystals more or less regular. But the crystallization does not take place unless the solution be concentrated. This solubility in water, and the capacity of crystallizing from the aqueous liquid, are two characteristic properties of sabadillina.

Alcohol dissolves several times its weight of this alkaloid, but no crystals can be obtained from the solution. It is quite insoluble in ether.

Concentrated sulphuric acid chars it, but, when sufficiently dilute, a *sulphate of sabadillina* may be formed, and obtained in crystals. Muriatic acid behaves with it in the same manner.

Nitric acid decomposes it entirely when assisted by heat, converting it into an acid resin with a trace of oxalic acid.

Chlorine deprives it of its hydrogen, and converts it into a brown friable mass.

M. Couerbe found sulphate of sabadillina composed of

Sulphuric acid . . .	5
Sabadillina	26·31

But the alkali contained 2 atoms of water. He subjected sabadillina to an ultimate analysis, by means of black oxide of copper, and obtained

* Ann. de Chim. et de Phys. lii. 373.

Carbon	63·41 or 20 atoms	=	15·000	or per cent.	64·18
Hydrogen	6·86 or 13 atoms	=	1·625	— —	6·96
Azote	7·94 or 1 atom	=	1·75	— —	7·48
Oxygen	21·79 or 5 atoms	=	5·0	— —	21·38
	100·00*		23·375		100

The gumresin obtained by M. Couerbe, while purifying veratrina, as described in the last Section, is a substance of a reddish colour, and very soluble in water. When heated gently, *in vacuo*, it assumes a spongy appearance, and becomes very friable. Its characters are those of an alkali. It saturates nearly as much acid as sabadillina, but does not form crystallizable salts. The acids throw it down from its acid combinations, but do not unite with it.

M. Couerbe analyzed it, and found its constituents the same as those of sabadillina, with the addition of an atom of water. Consequently its constituents may be represented thus, C^{20} H^{13} Az O^5 + H O.

SECTION VIII.—OF THEBAINA.

This substance was discovered by M. Thiboumery, who had the management of M. Pelletier's chemical establishment, in the year 1832. It was announced by M. Pelletier under the name of *paramorphina*. But M. Couerbe, who examined it and analyzed it in the year 1835, distinguished it by the name of *thebaina*, which we shall adopt.

M. Thiboumery, while engaged in extracting morphina from opium, employed slacked lime to throw it down from the aqueous infusion of opium. He obtained a clear liquid and a precipitate containing much lime. This precipitate being digested in alcohol, and the liquid concentrated, he obtained, instead of morphina, a substance which appeared to be new.† M. Couerbe passed a current of carbonic acid through the liquid from which the thebaina had been precipitated by lime. Carbonate of lime precipitated, and a good deal of morphina almost white and in silky crystals.‡

Thebaina thus obtained is perfectly white, and crystallizes in alcohol and ether. When crystallized in alcohol it forms protuberances like sugar of grapes. From ether the crystals are isolated, have a splendent lustre, and consist of very flat rhomboidal prisms.

Thebaina has strongly alkaline properties. At 266° it melts, and does not become solid at 230°. Narcotina melts at 338°, and becomes solid at 266°. Codeina melts at 302°. Meconin at 194°. Thus thebaina may be distinguished from the other constituents of opium by the temperature at which it enters into fusion.

* Ann. de Chim. et de Phys. lii. 378.

† I think it probable that *thebaina* does not exist ready formed in opium; but that it is evolved by the action of lime on morphina.

‡ Couerbe considers this mode of obtaining morphina as more economical than the common one. The morphina thus obtained may be converted into sulphate without previous solution in alcohol.

When the crystals of thebaina are melted they give out 4 per cent. of water. It will be seen immediately that the atom of thebaina is 26·75. Hence the crystals consist of

1 atom thebaina . . .	26·75
1 atom water . . .	1·125

M. Couerbe subjected it to an analysis in the usual way by means of oxide of copper, and obtained

Carbon	71·976 or 25 atoms	=	18·75	giving per cent.	71·44
Hydrogen	6·460 or 14 atoms	=	1·75	— —	6·66
Azote	6·385 or 1 atom	=	1·75	— —	6·66
Oxygen	15·179 or 4 atoms	=	4·00	— —	16·24
	100·000*		26·75		100·00

M. Couerbe found that 323 parts of thebaina absorb 27 parts of dry muriatic acid, and in another experiment that 60 parts absorb 5 of muriatic acid. If we consider the salt thus formed as a bimuriate, we have the atomic weight of thebaina 26·75.

It was analyzed in 1836 by Mr. Kane of Dublin, who obtained

Carbon	73·20
Hydrogen	6·85
Azote	6·94
Oxygen	13·01
	100·00†

This gives the formula

25 atoms carbon	= 18·75	or per cent.	74·25
14 atoms hydrogen	= 1·75	— —	6·93
1 atom azote	= 1·75	— —	6·93
3 atoms oxygen	= 3·00	— —	11·89
	25·25		100

This result differs from that of Couerbe by an atom of oxygen. According to Mr Kane, 100 parts of thebaina absorb 33·28 parts of muriatic acid. This would make the muriate a compound of

Muriatic acid . . .	4·625
Thebaina	13·89

It would seem from this that the salt formed by Mr Kane was a compound of

2 atoms muriatic acid . .	9·25
1 atom thebaina . . .	25·25
	34·5

By Couerbe's experiments 100 thebaina absorb only 8·35 of muriatic acid. His salt must have contained 2 atoms thebaina united to 1 atom muriatic acid.

None of the salts of thebaina have been hitherto examined. Nor is its effect upon the animal economy yet known.

* Ann. de Chim. et de Phys. lix. 156. † Ann. der Pharm. xix. 9.

SECTION IX.—OF DELPHINA.

Delphina was discovered, in 1819, by MM. Lassaigne and Feneulle* in the seeds of the *delphinium staphysagria* or *stavesacre*, a biennial plant, which grows in the South of Europe. The seeds are usually imported into this country from Italy. They are large, rough, of an irregular triangular figure, and of a blackish colour on the outside but yellowish within. Their smell is disagreeable and somewhat fœtid: to the taste they are very bitter, acrid, and nauseous. The ancients seem to have employed them as a masticatory. They are seldom used now-a-days except as an external application in some eruptions, and to destroy lice.

M. Couerbe proposes the following method of extracting delphina from these seeds:†—They are pounded in a mortar, and thus brought into the consistence of a paste. This paste is digested in boiling alcohol, of the specific gravity 0·837, till everything soluble is taken up. The alcohol is distilled off and a blackish-red extract left, containing much fatty matter and very acrid. Let it be boiled in water acidulated with sulphuric acid till it ceases to communicate any colour to that liquid, or till no precipitate is thrown down by an alkali dropt into it. The delphina is held in solution in the state of an impure sulphate, and a great quantity of fatty matter is left undissolved. Potash or ammonia will throw down the delphina from the solution containing the impure sulphate. Dissolve the precipitate in boiling alcohol, and treat the solution with ivory black. Filter and evaporate till the delphina is deposited. A pound of stavesacre furnishes from 55 to 60 grains of delphina.

Delphina thus obtained is still impure. In order to purify it let it be dissolved in water acidulated with sulphuric acid, filter the solution and pour into it, drop by drop, nitric acid diluted with half its weight of water. A dark-coloured resinous matter is precipitated, and the liquid,‡ which is now very acid, has lost all colour. Let the whole remain at rest for 24 hours; at the end of which time the resin will have attached itself to the bottom of the vessel. Decant off the clear liquid and decompose it by dilute potash. Dissolve the precipitate in alcohol of 0·817. This solution being filtered and distilled, we obtain a substance apparently resinous and of a yellowish colour. Digest it in boiling water, which dissolves a little nitre. Ether digested on the residual matter dissolves the pure delphina and leaves *staphysina*. By evaporating the ether the delphina is obtained in a state of purity.

Berzelius gives the following method, which is more easily executed:§—Digest the seeds in water acidulated with sulphuric acid. Precipitate the acid liquid by an alkali or by magnesia. Wash and

* Ann. de Chim. et de Phys. xii. 358. † Ibid. lii. 364.

‡ Unless the sulphate be diluted with a great quantity of water this resin carries down delphina along with it.

§ Traité de Chimie, v. 173.

dry the precipitate, and digest it in boiling alcohol, which will dissolve the delphina. Treat the solution with ivory black, filter and precipitate the delphina by ammonia. It has the form of a jelly. Being dissolved in alcohol and obtained by evaporation it assumes the form of a crystalline powder, which becomes opaque when dried.

Delphina has a slight amber colour. It is solid, soluble in ether, still more soluble in alcohol, but scarcely soluble in water whether cold or hot. The taste is excessively acrid, and it remains very long in the mouth. It does not crystallize. It melts at 248°. At a higher temperature it undergoes decomposition and is charred.

The dilute acids dissolve it without alteration; but concentrated acids decompose it. Nitric acid at the common temperature of the atmosphere has but little action in it, but when heated it alters its properties and converts it into a bitter and acid resin.

Chlorine at the usual temperature of the air has no action on it, but at the temperature of 300° or 320°, it attacks delphina with violence, gives it first a green colour and then a brown, and renders it very friable. Muriatic acid is formed, and the matter formerly soluble in alcohol is now only partially so. Ether dissolves an additional portion, and a powder of a deep chestnut-brown colour remains undissolved.

Couerbe found that 100 delphina absorbed 17·52 of muriatic acid, making the muriate

Muriatic acid . . .	4·625
Delphina	26·39

This gives 26·39 for the atomic weight of delphina.

From the analysis of delphina by Couerbe* and Henry,† its constituents are

	Couerbe.	Henry.				
Carbon	75·65	77·55	or 27 atoms =	20·25	or per cent.	77·14
Hydrogen	8·89	8·81	or 18 atoms =	2·25	— —	8·57
Azote	5·93	5·58	or 1 atom =	1·75	— —	6·67
Oxygen	9·53	8·06	or 2 atoms =	2·00	— —	7·62
	100·00	100·00		26·25		100·00

Delphina combines with acids and forms salts, which have an extremely bitter and acrid taste; but only a very few of them have been examined.

1. *Muriate of delphina.* This salt deliquesces when exposed to the atmosphere.

2. *Sulphate of delphina.* According to M. Feneulle, there are two species of this salt, neutral sulphate and disulphate of delphina.

* Ann. de Chim. et de Phys. lii. 366. † Jour. de Pharmacie, xx. 62.

When delphina is saturated with sulphuric acid and the solution is left to spontaneous evaporation we obtain a transparent hard mass resembling gum, which dissolves readily in water and in alcohol. The taste is at first bitter, and then acrid, and the impression remains long in the mouth.*

3. *Nitrate of delphina.* Delphina when saturated with weak nitric acid forms a colourless solution, which becomes yellow when concentrated. By evaporating to dryness we obtain a yellow crystalline mass.

4. *Oxalate of delphina* is obtained in white plates, having the same bitter and acrid taste as the other salts of delphina.

SECTION X.—OF NARCEINA.†

This substance was discovered by Pelletier, in 1832.‡ It may be obtained from opium, in the following manner :—

Let opium be digested several times in cold water, till every thing soluble be taken up. Evaporate the aqueous liquid to the consistence of an extract. Dissolve this extract in boiling water : a brilliant crystalline matter remains undissolved, which is narcotin.

Raise the aqueous solution to the boiling temperature, and add ammonia till it is in slight excess. Boil for a little, to drive off this excess as much as possible, then allow the liquid to cool. Abundance of morphina falls in the state of crystals ; while a crust of morphina, mixed with a matter, apparently resinous, swims on the surface of the liquid.

The greatest part of the morphina being thus separated, the remaining solution is concentrated to one half of its bulk, and set aside in a cool place. An additional precipitate of morphina falls.

Barytes water being added to the liquid thus freed from morphina,

* M. Feneulle has analzyed three different sulphates of delphina (Jour. de Pharmacie, ix. 5).

1. Sulphate by digesting an excess of delphina in dilute sulphuric acid, filtering and evaporating to dryness. It was composed of

Acid . . .	3·031 or 5	or 1 atom.
Delphina . .	95·969 or 159·96	or 6 atoms.
	100·000	

2. Sulphate composed of

Acid . . .	1·716 or 5	or 1 atom.
Delphina . .	98·284 or 286·3	or 11 atoms.
	100·000	

3. Supersulphate of delphina

Acid . . .	6·438 or 5	or 1 atom.
Delphina . .	100 77·6	or 3 atoms.
	106·438	

But these analyses cannot be depended on.

† Named probably from ναρκη torpor. ‡ Ann. de Chim. et de Phys. l. 247.

a precipitate of *meconate of barytes* falls, which is to be separated by a filter.

To the remaining liquid carbonate of ammonia is added, to throw down any excess of barytes that may have been introduced. Heat the liquid thus freed from barytes, and drive off the excess of carbonate of ammonia, and evaporate it to the consistence of a thick syrup. When brought to this consistence it is left for some days in a cool place. It assumes the form of a pulpy mass, among which crystals may be observed. This pulpy matter is put upon paper to dry, and then strongly pressed between folds of cloth to free it from a black viscid matter. It is now digested in boiling alcohol, which partly dissolves it.

The alcohol being distilled off, and the residual liquid allowed to cool, crystals are deposited, which are easily purified, by repeated solutions in water and crystallizations. These crystals constitute *narceina*. Should it be mixed with *meconin*, this last substance is easily separated by digestion in ether.

Narceina has a white colour, and silky lustre. It crystallizes in delicate four-sided prisms, having the aspect of needles. It has no smell; its taste is slightly bitter, and it gives an impression similar to what one perceives when he puts his tongue between two metallic plates of zinc and silver, and the two plates are brought into contact.

It dissolves in 230 times its weight of boiling water, and in 375 times its weight of water of the temperature of 57°. When heated to 198° it melts, and on cooling concretes into a white translucent mass, exhibiting vegetations on the surface, which show a tendency to crystallization. At 230° it becomes yellow, and when the heat is increased it is decomposed without subliming.

The concentrated mineral acids act upon narceina with great energy, and quite alter its nature. When the same acids are in a dilute state it combines with them; but it does not prevent them from reddening vegetable blues. When muriatic acid, diluted with one third of its weight of water, is placed in contact with narceina, the alkaloid assumes a fine blue colour. If we add enough of water to dissolve the compound, the solution is colourless. If we evaporate this solution, we obtain a violet-red crust, which passes at last into blue, if the liquid does not contain too much acid, in which case the crust is yellow, but the narceina is altered in its nature. When the blue colour is produced, the narceina is unaltered, for it may be precipitated with all its properties by an alkali. If we absorb the water from a muriatic solution of narceina, by means of chloride of calcium, we can obtain the red, violet, and blue colours in succession.

The dilute sulphuric and nitric acids produce the same phenomena as the muriatic. The peroxidized salts of iron do not strike a blue with narceina.

We have two analyses of narceina, one by Pelletier, and the other by Couerbe. The results are as follows:—

	Pelletier.*	Couerbe.†				
Carbon	54·73	57·018	or 28 atoms =	21·00	or per cent.	56·38
Hydrogen	6·52	6·637	or 20 atoms =	2·50	— —	6·71
Azote	4·33	4·760	or 1 atom =	1·75	— —	4·70
Oxygen	34·42	31·585	or 12 atoms =	12·00	— —	32·21
	100·00	100·000		37·25		100

This would make the atomic weight 37·25, which, from analogy, ought to be pretty near the truth, admitting the accuracy of Couerbe's analysis.

When narceina is exposed to a temperature above 230° it swells, gives out vapours, at first white, and afterwards yellow, and leaves a bulky charcoal. We find in the receiver an acid liquid, a brown bituminous liquid, having a balsamic odour, together with some white crystalline needles, which seem to be crystals of gallic acid.‡

SECTION XI.—OF CODEINA.§

This substance was discovered in opium by M. Robiquet, in 1832, while occupied in examining the process of Dr Robertson of Edinburgh, for extracting morphina from opium, by means of chloride of calcium.‖

This method consists in macerating opium in water, concentrating the infusion, and mixing it with chloride of calcium. Meconate of lime precipitates, while muriates of morphina and codeina remain in solution. These salts are obtained in crystals, by concentrating the liquid sufficiently, and the crystallizations are repeated till the salts are quite white. They are then dissolved in water, and the morphina precipitated by ammonia. The codeina remains in the solution.

To obtain it the residual liquid is concentrated, and a crystalline mass obtained, which is pressed between folds of blotting paper, and digested in boiling water. A portion only dissolves, which, as the liquid cools, is deposited in silky tufts of crystals, perfectly white. When these crystals are treated with a solution of caustic potash, a pulverulent hydrate of codeina is deposited, which is first washed in a little cold water, and after being dried, is digested in boiling ether. A portion of the powder is dissolved, and the liquid, when evaporated spontaneously, deposits small radiated plates, which are hard and transparent, and at last a liquid remains of the consistence of syrup. When a little water is added to this liquid, a number of white crystals are deposited in needles. These are collected on a filter, and washed with a little water. When dried they

* Ann. de Chim. et de Phys. l. 268. † Ibid. lix. 151.
‡ Pelletier, Ann. de Chim. et de Phys. l. 267.
§ Named probably from κωδη, the fruit of the poppy.
‖ Ann. de Chim. et de Phys. li. 259.

constitute pure *codeina*. 100 lbs. of opium yield about six ounces of it.

It has been hitherto very imperfectly described. When exposed to heat on platinum foil it burns with flame. When heated in a tube it melts at 302°, and on cooling concretes into a crystalline mass.

It possesses alkaline properties. 1000 parts of water at 59° dissolve 12·6 parts of it; at 110°, 37 parts; and at 212°, 58·8 parts. When added in excess to boiling water, it gives out its water of crystallization, and then melts, assuming the appearance of an oil.

Codeina is insoluble in alkaline solutions. It combines with acids, and forms salts, several of which crystallize. The nitrate in particular crystallizes very readily. The tincture of nutgalls occasions a copious precipitate in solutions of codeina.

Hydriodate of codeina is a white salt, which may be obtained by dissolving codeina directly in hydriodic acid. It is very similar to hydriodate of morphina, but cannot, like it, be decomposed by ammonia. Iodic acid dissolves codeina; but Pelletier did not succeed in obtaining the iodate in crystals, except there was an excess of acid present. The crystals were flat needles.*

Nitric acid does not change codeina to red as it does morphina; nor does it strike a blue with the persalts of iron.

Couerbe analyzed muriate of codeina, and found it composed of

Muriatic acid . . .	4·625
Codeina	36·25

Robiquet found that 100 parts of codeina crystals contain 6·5 water. Hence they are composed of

1 atom codeina . . .	36·25
2 atoms water . . .	2·25
	38·5

According to M. O. Henry, tannate of codeina is composed of

Tannin . . .	62 or 59·14
Codeina . . .	38 or 36·2
	100†

Now, $3\frac{1}{2}$ atoms of tannin = 58·1878. It would seem, therefore, as if this salt were composed of $3\frac{1}{2}$ atoms tannin, and 1 atom codeina.

Robiquet‡ and Couerbe§ subjected codeina to an ultimate analysis, and obtained for its constituents

* Ann. de Chim. et de Phys. lxiii. 194.

† Jour. de Pharmacie, xxi. 221.

‡ Ann. de Chim. et de Phys. li. 265. § Ibid. lix. 158.

	Robiquet.	Couerbe.			
Carbon	71·339	72·846	or 32 atoms =	24·0	giving 72·46
Hydrogen	7·585	7·148	or 19 atoms =	2·375	— 7·17
Azote	5·353	5·231	or 1 atom =	1·75	— 5·28
Oxygen	15·723	14·775	or 5 atoms =	5	— 15·09
	100·000	100·000		33·125	100·00

Dr William Gregory has made some experiments on the action of nitrate of codeina on the animal economy. When administered in doses of from 4 to 6 grains, it produces an excitement, similar to intoxication, which in a few hours is followed by a disagreeable depression, accompanied by nausea, and sometimes by vomiting. M. Kunkel has remarked that codeina loses a good deal of its activity when combined with acids. Hence it is probable that a simple aqueous solution of codeina would be more active than the nitrate.*

SECTION XII.—OF STRYCHNINA.

Strychnina was discovered, in 1818, by MM. Pelletier and Caventou.† It exists in the seeds or fruits of several species of *strychnos*, particularly in the *nux vomica*, the fruit of the *strychnos nux vomica;* in *St Ignatius' bean*, the fruit of the *strychnos ignatia*, and in that of the *strychnos colubrina* or *snakewood*. It was found also in the poisonous matter called *upas*, which the natives of the Indian Archipelago employ to poison their arrows.

From St Ignatius' bean Pelletier and Caventou extracted strychnina by the following process:—

The beans were grated down to a kind of powder, and then digested in ether as long as any soluble matter could be extracted. The residual matter was treated a great many times successively with boiling alcohol. The alcohol being distilled off, a yellowish-brown matter remained, having an exceedingly bitter taste, and soluble both in water and alcohol. When this substance was treated with caustic potash a precipitate was obtained, which, after being washed in cold water, furnished a white crystalline matter, having an excessive bitter taste. It was strychnina.

To obtain strychnina from nux vomica, an alcoholic extract is obtained, which is dissolved in water. To the solution diacetate of lead is added as long as any precipitate falls. The strychnina remains in solution, united to acetic acid. The solution contains, besides, colouring matter and an excess of the diacetate of lead. This excess is thrown down by sulphuretted hydrogen, and the liquid is then boiled with magnesia, which precipitates the strychnina. It is washed in cold water, and dissolved in alcohol which frees it from the magnesia employed in excess. When the alcohol is evaporated, the strychnina is obtained in a state of purity. It is by a similar process that it is obtained from snakewood.

* Jour. de Pharmacie, xx. 85.

† Jour. de Pharmacie, v. 173, and Ann. de Chim. et de Phys. x. 142.

M. Henry* extracts strychnina from nux vomica, by the following process:—The nux vomica is grated down to powder, and treated with water till every thing soluble is extracted. These decoctions being evaporated to the consistence of a syrup, lime in a pulverized state is added, care being taken to employ it in slight excess. The lime forms an insoluble salt with igasuric acid, which seems to exist in nux vomica combined with strychnina. It precipitates the strychnina, and some other substances. The digestion, with lime, is continued for several hours. The precipitate is then washed, and digested in alcohol of the specific gravity 0·827, which dissolves the strychnina and some colouring matters.

The alcohol being distilled off by the water-bath, the strychnina is obtained in brilliant crystals, together with a small quantity of dark-coloured liquid, containing some strychnina. By repeatedly dissolving these crystals in alcohol, or still better, by combining them with nitric acid, crystallizing the nitrate, dissolving the crystals in water, and throwing down the strychnina by ammonia, it is obtained pure. 1000 parts of nux vomica, by this process, furnish 5 or 6 parts of strychnina.

M. Henry, junior,† has proposed the following process, which he considers the best of all those hitherto proposed:—

Nux vomica is reduced by grinding to a fine powder. It is digested under the heat of the water-bath with alcohol of the specific gravity 0·856, and acidulated with sulphuric acid. For every kilogramme (15433 grains) of nux vomica, 40 to 50 grammes of sulphuric acid and from 4 to 5 litres of alcohol must be employed.‡ Or for every avoirdupois pound weight of nux vomica, add 280·6 grains, or about 10 drams of sulphuric acid, and 111 cubic inches, or rather more than 3 imperial pints of alcohol.

Two digestions in alcohol take place, and the residual undissolved nux vomica is subjected to pressure, and all the alcoholic liquids being mixed together, an excess of quicklime in powder is added, sufficient to saturate the acid and to throw down the colouring matter. The alcoholic liquor, which has a light-amber colour, is decanted off the precipitate. The precipitate is washed with alcohol, and all the liquids are carefully filtered, and the alcohol is distilled off. There remains a greenish-brown, pitchy alkaline matter, which is to be saturated with water weakly acidulated with sulphuric, muriatic, or acetic acid. The neutral liquid is filtered, concentrated, and precipitated cold, by adding a slight excess of ammonia.

The precipitate which falls is washed, and digested in hot alchol, of the specific gravity 0·942, in order to dissolve the *brucina*.

The strychnina is then dissolved in boiling alcohol of 0·837, and treated with a little animal charcoal to remove the colouring matter. When the liquid is allowed to cool the strychnina crystallizes.

* Jour. de Pharmacie, viii. 401. † Ibid. xvi. 752.

‡ The gramme is 15·433 grains, and the litre contains 61·028 cubic inches.

According to Wittstock,* 1 lb. of nux vomica yields 40 grains of nitrate of strychnina, and 50 grains of nitrate of brucina, when treated in the following way:—

Boil the nux vomica with alcohol of the specific gravity 0·94. Decant off the liquid, and dry the nux vomica in an oven. It is thus rendered easily pulverizable. Digest the powder in alcohol, till every thing soluble is taken up. Distil off the alcohol, and treat the residual liquid with acetate of lead, as long as a precipitate continues to fall. By this process the colouring matter, the fatty matter, and the acids present in the solution are separated. Throw the whole on a filter, wash the deposit, and evaporate the liquid, till for every pound of nux vomica employed, there remains from 6 to 8 ounces of liquid. Add 2 gros of magnesia,† and allow the mixture to remain at rest for some days, that the brucina may have time to be deposited. Collect the deposit on a cloth, expose it to pressure, dry it, and digest it in alcohol of 0·83. When the alcohol is distilled the strychnina is deposited in the state of a white crystalline powder, while the brucina remains in the mother water.

When strychnina is obtained by the spontaneous evaporation of an alcoholic solution, it assumes the form of octahedrons, composed of two four-sided pyramids, between which a four-sided prism is sometimes interposed.

Its taste is intensely bitter, and it leaves an impression in the mouth similar to that produced by certain metallic salts. It is destitute of smell.

It acts with great energy on the animal economy, being a most virulent poison, and proving equally fatal whether it be taken into the stomach, or mixed with the blood by being introduced into a wound. Death ensues very rapidly, often in a few minutes. It occasions violent contractions of the muscles, and induces tetanus. The best antidote is infusion of nutgalls, or warm tea. But its action is so rapid, that it is seldom in our power to apply any remedy. In small doses ($\frac{1}{10}$th grain) it has been tried in paralysis, and, it is said, sometimes with success.

It undergoes no alteration when exposed to the air; and does not melt nor lose any weight when heated up to 248°. It is decomposed when heated to about 600°.

It requires 2500 times its weight of boiling water, and 6667 times its weight of cold water to dissolve it. But this last solution, weak as it is, has a decidedly bitter taste. Anhydrous alcohol does not dissolve it. At the temperature of 60°, alcohol of 0·820 dissolves only a trace of it. Alcohol of 0·835 dissolves a sensible quantity of it at the boiling temperature.

It is scarcely soluble in ether. The volatile oils dissolve it, and when a boiling solution is allowed to cool, part of the strychnina crystallizes. The fixed oils acquire a bitter taste, but dissolve very little of it.

* Berzelius's Traité de Chimie, v. 142. † The gros is 72 grains.

M. Pelletier formed the iodide of strychnina, by triturating the alkali with half its weight of iodine, digesting in water, filtering, and dissolving the brown residue in boiling alcohol. The solution had an orange colour, and deposited small yellow crystalline plates, resembling Mosaic gold. These crystals consisted of iodide of strychnina. Towards the end of the evaporation, white needle-form crystals fell, consisting of muriate of strychnina.

Iodide of strychnina is insoluble in cold, and very little soluble in boiling water. It is but little soluble in alcohol of 0·817. Its best solvent is boiling alcohol of the specific gravity 0·837. It crystallizes on cooling. Ether does not dissolve it.

At first it seems tasteless, but some bitterness and astringency becomes gradually perceptible. It is infusible at the temperature of 212°, and at every temperature below that at which it undergoes decomposition. When heated on platinum foil it swells, softens, emits iodine, and is charred.

Very dilute acids have no action on it while cold, but decompose it by long boiling. Nitric acid, when concentrated, disengages iodine without the assistance of heat. Sulphuric acid acts in the same way, but with less energy. Muriatic acid has no action while cold; but when assisted by heat it disengages iodine. Potash and soda, when aided by heat, disengage strychnina, while an iodide of potassium or sodium is formed. Ammonia has no action on it. Pelletier analyzed this iodide, and found it composed of

1 atom iodine . . .	15·75
1 atom strychnina . . .	31
	46·75*

We have three analyses of strychnina, one by Pelletier and Dumas, another by Liebig, and a third by Henry and Plisson. The following table exhibits the results of these analyses:—

	Pelletier & Dumas†	Liebig.‡	Henry & Plisson.§
Carbon	78·22	75·35	76·4
Hydrogen	6·54	6·70	7·8784
Azote	8·92	5·81	7·5036
Oxygen	6·38	12·14	8·2190
	100·06	100	100

Liebig found that 100 parts of strychnina absorbed 15·02 of muriatic acid.‖ Hence muriate of strychnina is a compound of

Strychnina . . .	30·792
Muriatic acid . . .	4·625

According to this experiment the atomic weight of strychnina is 30·792. But, in another experiment, he finds that 100 strychnina

* Ann. de Chim. et de Phys. lxiii. 165. † Ibid. xxiv. 180.
‡ Poggendorf's Annalen, xxi. 21. § Jour de Pharmacie, xvii. 453.
‖ Poggendorf's Annalen, xxi. 21.

absorb 14·6 muriatic acid.* This would raise the atomic weight to 31·74.

By another analysis he found sulphate of strychnina composed of strychnina 86·102, and sulphuric acid 13·828.† Hence the constituents are

Strychnina	31·13
Sulphuric acid . . .	5

The mean of these analyses gives 31·22 for the atomic weight of this alkali.

Now, the number of atoms which agree best with the preceding analyses is the following:—

30 atoms carbon	= 22·50	or per cent.		76·93
16 atoms hydrogen	= 2·00	—	—	6·84
1 atom azote	= 1·75	—	—	5·98
3 atoms oxygen	= 3·00	—	—	10·25
	29·25			100·00

But they do not coincide with the atomic weight. Doubtless the atoms of oxygen in strychnina are 4, and not 3, as Liebig has supposed.

When heated strongly, strychnina swells, blackens, gives out an empyreumatic oil, and a little ammoniacal water. It gives out carbonic acid and carburetted hydrogen, while a bulky charcoal remains behind.

When a mixture of strychnina and sulphur is heated, the strychnina is decomposed, and a great quantity of sulphuretted hydrogen gas is evolved. When a mixture of strychnina and iodine is boiled in water, the colour of the iodine disappears, and the strychnina is dissolved abundantly, assuming, in the first place, a red colour. When a current of chlorine is passed through water, holding strychnina in suspension, the latter is dissolved; and when the solution is evaporated, pure crystals of muriate of strychnina are obtained.

The salts of strychnina have been more examined than those of any of the other alkaloids. They are all soluble in water, have an intensely bitter taste; and when taken into the stomach, or introduced into the circulation, prove fatal, by inducing tetanus. When nitric acid is poured upon a salt of strychnina, and heat applied, the salt assumes a beautiful red colour; but this is owing to the presence of a foreign matter. They are precipitated by the infusion of nutgalls, and the precipitate is soluble in alcohol.

1. *Muriate of strychnina.* This salt crystallizes in very fine needles, usually grouped together in tufts. When exposed to a dry atmosphere, these crystals become opaque. This salt is pretty soluble in water. When heated to the temperature at which the base begins to be decomposed, it lets go the muriatic acid.

When corrosive sublimate is poured into a solution of muriate

* Ann. de Chim. et de Phys. xlix. 245. † Ibid.

of strychnina, a double salt is deposited in white flocks. The cyanodide of mercury produces an analogous deposit.

2. *Hydriodate of strychnina.* This salt crystallizes in white flat needles. It is so little soluble in cold water, that it precipitates when a solution of iodide of potassium is dropt into a salt of strychnina. Its taste is bitter, and from the experiments of Pelletier, it appears to be a compound of 1 atom hydriodic acid, and 1 atom strychnina.*

3. *Hydrocyanate of strychnina.* This salt is obtained by dissolving strychnina in prussic acid. It may be evaporated to dryness without losing its acid.

4. *Sulphate of strychnina.* This salt crystallizes in cubes, and requires ten times its weight of water to dissolve it. Its taste is exquisitely bitter, and it is decomposed by all the salifiable bases which throw down the strychnina. This salt loses its water when heated to 212°.

If we add a little sulphuric acid to a neutral sulphate of strychnina, evaporate to dryness, and digest the residue in ether to remove the excess of acid, we obtain a *bisulphate of strychnina*, which crystallizes in fine needles, and has a taste at once bitter and acid.

5. *Cupreous sulphate of strychnina.* This salt may be obtained by boiling strychnina in a solution of sulphate of copper, filtrating the liquid, which has a pale-green colour, and crystallizing. The salt forms long needles, having a green colour.

6. *Nitrate of strychnina.* To prepare this salt, we must dilute nitric acid, and heat it with a greater proportion of strychnina than is sufficient to saturate it. When the liquid is evaporated, it yields crystals of nitrate of strychnina in pearl-coloured needles, grouped together in the form of stars. Its taste is excessively bitter, and it acts with more violence on the animal economy than pure strychnina. It is much more soluble in hot than in cold water.

When heated a few degrees above 212° it becomes yellow, and undergoes decomposition. If we increase the heat the salt swells, blackens, and a noise is heard similar to that of nitre in a state of fusion. But no light appears if the salt be neutral. This salt is slightly soluble in alcohol, but insoluble in ether.

If to a hot saturated solution of nitrate of strychnina we add a little nitric acid, crystals of *binitrate of strychnina* are deposited as the liquid cools. They have the form of very fine needles. When heated they become red, and by augmenting the temperature they are decomposed with a kind of detonation and evolution of light. Pelletier and Caventou have shown, that this red colour is owing to the presence of a small quantity of foreign matter derived from the *nux vomica* and attached to the strychnina. In the upas there is a similar matter, but it is converted into *green* by nitric acid, instead of into *red*.

* Ann. de Chim. et de Phys. lxiii. 172.

7. *Carbonate of strychnina.* This salt may be obtained by mixing an alkaline carbonate with a salt of strychnina, or by passing a current of carbonic acid gas through water in which strychnina is suspended. The solution gradually deposits granular crystals, slightly soluble in water.

8. *Phosphate of strychnina.* This salt crystallizes in four-sided prisms. When we prepare it by dissolving strychnina in phosphoric acid, the liquid still retains the property of reddening vegetable blues. But this does not hinder the four-sided prisms from being deposited. Probably they constitute a biphosphate.

9. *Chlorate of strychnina.* This salt may be obtained by saturating dilute chloric acid with strychnina. When the solution is heated it becomes coloured, and the salt crystallizes in small short prisms. If the solution is concentrated, it becomes almost a solid mass on cooling.

10. *Iodate of strychnina.* When a solution of iodic acid is heated moderately in contact with strychnina, it assumes a wine-red colour. When the concentrated solution is left in a cool place, it deposits transparent crystals in long needles in tufts, superficially stained red, but rendered colourless when washed on a filter with a little cold water.* They are very soluble in water, and are decomposed when suddenly heated.

From the analysis of Pelletier, it appears that this salt is composed of 1 atom iodic acid and 1 atom strychnina.*

11. According to M. O. Henry, tannate of strychnina is composed of

Tannin . . .	63·93 or 54·94
Strychnina . .	36·07 or 31
	100·00†

It is, therefore, a tertannate.

12. The *acetic*, *tartaric*, and oxalic acids, form with strychnina neutral salts, very soluble in water, and more or less capable of assuming regular crystalline forms.

SECTION XIII.—OF BRUCINA.

Brucina was discovered by Pelletier and Caventou, in 1819, in the bark of the *brucea antidysenterica*.‡ This bark has been introduced into medicine as a substitute for *angustura*, and had been distinguished by the name of *false angustura*. Brucea was named from Bruce, the Abyssinian traveller, who first brought the seeds of the shrub from Abyssinia, and they afterwards vegetated in the botanic gardens of Europe. Brucina was afterwards detected along with strychnina in *nux vomica*, and has been found in general to accompany that alkali in the different vegetable bodies which contain it.

Pelletier and Caventou extracted *brucina* from the false angustura,

* Ann. de Chim. et de Phys. lxiii. 170. † Jour. de Pharmacie, xxi. 221.

‡ Journal de Pharmacie, vi. 529. It is now considered as the bark of the *strychnos nux vomica*.

in the following way :—A kilogramme ($2\frac{1}{3}$ lbs. avoirdupois) of the bark reduced to a coarse powder, was digested in ether to remove the greatest part of the fatty matter which it contains. It was then digested in strong alcohol. The alcoholic solutions were distilled over the water-bath to drive off the alcohol, and the residual matter was dissolved in water, and the solution mixed with diacetate of lead to throw down the colouring matter, and the excess of lead was got rid of by a current of sulphuretted hydrogen gas.

The brucina is then thrown down by magnesia. But as it is somewhat soluble in water, we must evaporate the liquid. A brown granular alkaline mass is obtained, having a pretty deep colour.

The oxalate of brucina being almost insoluble in absolute alcohol, the granular matter is saturated with oxalic acid, and the oxalate is washed with absolute alcohol, at the temperature of 32°. The colouring matters are dissolved, and the oxalate of brucina remains perfectly white. This oxalate is decomposed by lime or magnesia. The brucina is dissolved in boiling alcohol and obtained in crystals when the solution cools.

According to Thenard, we may extract *brucina* with economy from the false angustura bark, by digesting the bark in water, and adding oxalic acid to the decoctions. If we evaporate the liquid to the consistence of an extract, and digest this extract in alcohol at 32°, every thing will be dissolved but the oxalate of brucina, which is to be treated in the way just described.

The brucina remaining in the washings of strychnina, described in the last Section, may be extracted in the following way :—Evaporate the liquid to the consistence of a syrup, and add to it dilute sulphuric acid, exceeding very little the point of saturation. In two or three days abundance of crystals will be formed. Put them into a cloth and expose them to strong pressure, to force out a viscid liquid mixed with them, and then wash them in a little cold water. Dissolve them in boiling water, treat the solution with animal charcoal, and filter. Ammonia throws down from this liquid the brucina in a state of purity.

The crystals of brucina are oblique four-sided prisms. By rapid crystallization it is obtained in scales, having a pearly lustre, and resembling boracic acid.

It requires 500 times its weight of boiling water, and 850 times its weight of cold water to dissolve it. The colouring matter when present greatly increases the solubility of *brucina*.

Its taste is intensely bitter, but it has a degree of acridity which is wanting in strychnina. It acts upon animals in the same way as strychnina, but is a much less active poison.

It is not altered by exposure to the air. When heated, it melts, and on cooling concretes into a mass resembling wax. Its melting point is a little above 212°. It gives out about 17 per cent. of water, and is therefore composed of

1 atom brucina . . .	35
6 atoms water . . .	6·75

The small excess of water is, doubtless, hygrometrical.

When reduced to powder, and mixed with water, it recovers its water in a few days.

It dissolves readily in absolute alcohol, and even in alcohol of the specific gravity 0·88. Ether and the fixed oils do not dissolve it, but in the volatile oils it is slightly soluble.

One of the most characteristic properties of brucina is that the red or yellow colour which it assumes when treated with nitric acid changes to a fine violet, when we add a little protochloride of tin, while at the same time a precipitate of the same colour falls. This property enables us to distinguish brucina from morphina and strychnina. When strychnina is mixed with brucina, we can easily by this test discover the presence of this last substance.

Brucina combines with iodine in two proportions, and forms two iodides, the first neutral, the second a biniodide.

If into an alcoholic solution of brucina, we pour an alcoholic solution of iodine, taking care to avoid all excess of the latter, and not to apply heat, an orange-coloured powder falls, which is an iodide of brucina, composed of

1 atom iodine . . .	15·75
1 atom brucina . . .	35
	50·75*

When brucina is saturated with iodine, and the brownish-yellow mass formed is digested in boiling alcohol of 0·837, a complete solution is obtained, which on cooling deposits a light-brown coloured powder. Its properties are similar to those of iodide of strychnina, but it does not crystallize, and is composed of

2 atoms iodine . . .	31·5
1 atom brucina . . .	35
	66·5†

Brucina has been analyzed by Pelletier and Dumas, by Liebig, and by Henry and Plisson. They obtained the following constituents:—

	P. & D.‡	Liebig.§	Henry & Plisson.‖
Carbon	75·04	69·82	70·48
Hydrogen	6·52	6·66	7·8108
Azote	7·22	5·07	6·7938
Oxygen	11·21	18·45	14·9154
	99·99	100·00	100

Liebig found that 850 parts of dry brucina absorbed 111 parts of dry muriatic acid gas.

According to this experiment, muriate of brucina is composed of

Muriatic acid	4·625
Brucina	35·41

This gives 35·41 for the atomic weight of brucina.

* Pelletier, Ann. de Chim. et de Phys. lxiii. 178. † Ibid. lxiii. 176.
‡ Ann. de Chim. et de Phys. xxiv. 179. § Poggendorf's Annalen, xxi. 22.
‖ Jour. de Pharmacie, xvii. 453.

Liebig also analyzed sulphate of brucina and found it composed of

Brucina . . .	77	35
Sulphuric acid . .	11	5
Water . . .	12	5·45
	100*	

According to this analysis, the atom of brucina weighs 35, and the salt contains a quantity of water exceeding 4 atoms, but rather less than 5 atoms. Now the number of atoms agreeing best with Liebig's analysis, which gives 35 for the atomic weight, are the following :—

32 atoms carbon	= 24	or per cent. 68·57
18 atoms hydrogen	= 2·25	— — 6·43
1 atom azote	= 1·75	— — 5·00
7 atoms oxygen	= 7·00	— — 20·00
	35·00	

These atomic proportions must very nearly represent the constitution of this alkaloid.

The salts of brucina have not been so much examined as those of strychnina. Their taste is bitter, and most of them are capable of crystallizing. They are decomposed by the alkalies, and also by morphina and strychnina, which throw down the brucina.

1. *Muriate of brucina.* This salt is neutral, and is easily obtained in four-sided prisms terminated by a slightly oblique face. It crystallizes frequently in very fine needles. It is not altered by exposure to the air. It is very soluble in water. When heated to the point at which the alkaloid begins to be decomposed, it allows its acid to escape.

2. *Hydriodate of brucina.* This salt may be obtained by dissolving brucina in hydriodic acid. It crystallizes in transparent short rectangular prisms. It is more soluble in cold water than hydriodate of strychnina and is very soluble in hot water, but crystallizes as the liquid cools. It is more soluble in alcohol than in water. According to the analysis of Pelletier, it is a subsesquisalt, being composed of

1 atom hydriodic acid . .	17·875
1½ atom brucina . . .	52·5
	70·375†

3. *Sulphate of brucina.* The neutral salt crystallizes in long slender needles, not unlike sulphate of morphina. It is very soluble in water, and slightly so in alcohol. Its taste is intensely bitter. When exposed to the air it effloresces, and loses two atoms water, according to Liebig.

The *bisulphate of brucina* may be formed by adding a little water to the solution of the neutral sulphate. Ether removes any excess

* Ann. de Chim. et de Phys. xlix. 247. † Ibid. lxiii. 180.

of acid that may have been added, but leaves the bisalt. It crystallizes readily.

3. *Nitrate of brucina.* This salt can only be obtained by dissolving brucina in very dilute acid. Strong nitric acid alters the alkaloid, and strikes with it a red colour. The nitrate does not crystallize, but when evaporated assumes the appearance of gum.

The *binitrate* crystallizes readily in four-sided prisms, terminated by bihedral summits. When heated, it becomes red, and if the heat be increased, it blackens and inflames.

4. *Phosphate of brucina.* The neutral salt does not crystallize. The *biphosphate* crystallizes readily in rectangular tables with bevelled edges. It is very soluble in water, and when exposed to the air effloresces slightly. Absolute alcohol scarcely dissolves it.

5. *Chlorate of brucina.* When dilute chloric acid is heated with brucina, it assumes a red colour. The solution crystallizes on cooling, in regular and transparent rhomboids. The crystals are at first reddish, but we obtain them colourless by a second crystallization.

6. *Iodate of brucina.* Brucina combines with iodic acid, without any sensible reaction. The solution is colourless, if neutral, but the addition of nitric acid strikes a lively red-colour. The neutral iodate can exist only in solution. By evaporation and rest, two salts are obtained from it: the one opaque and silky, the other transparent, hard, and in four-sided prisms. The former of this is a subsalt restoring the blue colour of litmus reddened by acids: the latter is a supersalt which reddens litmus paper. The subsalt has such a tendency to form that it appears frequently, when a solution of iodate of brucina slightly acid is left to crystallize.*

7. *Oxalate of brucina.* This salt crystallizes in long needles, especially when it contains an excess of acid. It is very soluble in absolute alcohol.

8. *Acetate of brucina.* This salt is very soluble in water, and does not seem capable of crystallizing.

9. According to M. O. Henry, tannate of brucina is composed of

Tannin . . .	60·45 or 53·49
Brucina . . .	39·55 or 35
	100·00†

It is therefore a tertannate.

SECTION XIV.—OF EMETINA.

This alkaloid was detected, in 1817, by MM. Magendie and Pelletier,‡ in ipecacuanha, but in a state of great impurity. Methods were afterwards discovered of separating the impurities,

* Pelletier, Ann. de Chim. et de Phys. lxiii. 179.
† Jour. de Pharmacie, xxi. 221. ‡ Ann. de Chim. et de Phys. iv. 172.

and these processes have been described by MM. Pelletier and Dumas.*

It is obtained from the various roots sold by apothecaries under the name of ipecacuanha. These are the roots of the *cephælis emetica*, *callicocca ipecacuanha* and *viola emetica*. But the true ipecacuanha is the root of the *cephælis ipecacuanha*, a native of the forests of Brazil. The method of obtaining the emetina from this root is the following:—

The root reduced to powder is treated with ether, which dissolves a fatty matter with a strong smell. It is then digested in boiling alcohol. This solution is filtered, mixed with a little water, and the alcohol distilled off. During this process a quantity of fatty matter is deposited, which must be separated by the filter. It is then boiled with an excess of magnesia, which precipitates the emetina and separates it from the acid with which it had been previously combined. Decant off the liquid, and wash the precipitate with cold water in order to remove some colouring matter. It is then to be carefully dried and the emetina separated from the excess of magnesia by digesting it in rectified spirits. To have it still whiter it may be dissolved in a dilute acid and the solution digested with ivory-black. The filtered liquid is to be treated with magnesia as before, and the emetina dissolved in alcohol.

Emetina thus obtained is white, though sometimes it assumes a yellowish tinge, and is under the form of a powder. When exposed to the air it undergoes no other alteration than becoming a little coloured. It is but little soluble in cold water; but more so in hot water. It is very fusible, becoming liquid when heated to 122°. It is very soluble in alcohol; but ether and oils do not act sensibly on it.

It possesses decided alkaline properties, combining with and neutralizing the acids; but none of its salts hitherto examined are capable of crystallizing.

Concentrated nitric acid alters it with great facility, forming first a bitter tasted resinous-looking matter, and, finally, oxalic acid. Gallic acid and infusion of nutgalls form in solutions of emetina very abundant white precipitates. Neither the oxalates nor tartrates precipitate emetina as they do quinina. The diacetate of lead, which occasions a copious precipitate in the coloured solutions of emetina, has no action whatever upon it when pure.

It acts very powerfully as an emetic. Half a grain taken into the stomach occasions violent vomiting, followed by sleep, and the animal awakes in a state of health. 12 or even 6 grains occasioned vomiting, followed by death. Pure emetina is about three times as strong as the black matter first described by Pelletier; $\frac{1}{16}$th of a grain has been found to constitute a sufficient dose, and this alkaloid has already been introduced into medicine as a substitute for powder of ipecacuanha.

It was analyzed by Pelletier and Dumas, who obtained

* Ann. de Chim. et de Phys. xxiv. 180.

Carbon	64·57
Hydrogen	7·77
Azote	4·00
Oxygen	22·95
	99·29*

Dumas considers it as a compound of

30 atoms carbon	= 22·5	making	per cent.	63·83
24 atoms hydrogen	= 3	—	—	8·51
1 atom azote	= 1·75	—	—	4·96
8 atoms oxygen	= 8	—	—	22·70
	35·25			100·00

But these numbers deviate too far from the result of the analysis to be admitted. The following formula tallies far better with the products obtained by Dumas :—

35 atoms carbon	= 26·25	or	per cent.	65·43
25 atoms hydrogen	= 3·125	—	—	7·78
1 atom azote	= 1·75	—	—	4·36
9 atoms oxygen	= 9·00	—	—	22·43
	40·125			100

SECTION XV.—OF SOLANINA.

Solanina was discovered by M. Desfosses in the berries of the *solanum nigrum*, and in the fruit of the common potatoe.† It has been found also in several other species of *solanum*, particularly the *dulcamara* or common *nightshade* of the hedges. M. Otto discovered it also in the potatoe itself after it had been allowed to germinate.‡ And Buchner detected a little of it in the precipitate by ammonia from the clarified juice of the potatoe.§

To obtain solanina we have only to express the juice of the ripe berries of *solanum nigrum* and add ammonia to the liquid. The alkaloid is thrown down in a greyish powder. It is to be dissolved in boiling alcohol and the solution digested with a little ivory black. The liquid, being filtered and evaporated, deposits solanina in a state of purity.

Solanina is a white powder, having a pearly lustre, and not acting upon turmeric paper. Yet it restores the colour of litmus paper reddened by an acid. When treated with caustic potash very little ammonia is disengaged; but when muriate of solanina is heated in a retort it gives off an oily liquid which, when treated with slacked lime, gives out a notable quantity of that alkali.

Solanina dissolves readily in the acids, and is precipitated from these solutions by the more powerful bases. Few of its salts crys-

* Ann. de Chim. et de Phys. xxiv. 182. They do not give the data for this composition, and do not tell us why there is a deficiency of 0·71 in the sum.

† Jour. de Pharmacie, vi. 374. and vii. 414.

‡ Ann. de Chim. et de Phys. liii. 412.

§ Repert. xlviii. 345, as quoted in Berzelius' Jahres-Bericht for 1835, p. 286.

tallize. Most of them assume the appearance of gum when evaporated to dryness.

It is an acrid narcotic poison. Two grains of the sulphate of solanina given to a rabbit produced death in a few hours. The death of the animal was preceded by paralysis of the posterior extremities.

We have an analysis of solanina by M. Blanchet,* from which it appears that its constituents are

Carbon	58·67
Hydrogen	8·96
Azote	1·64
Oxygen	30·73
	100·00

According to Desfosses, sulphate of solanina is composed of

Sulphuric acid . . .	5
Solanina	45·8

This would make the atomic weight of solanina 45·8.

Now the number of atoms which correspond best with this atomic weight and with Blanchet's analysis are

37 atoms carbon	= 27·75	or per cent. 59·80
34 atoms hydrogen	= 4·25	— — 9·07
½ atom azote	= 0·875	— — 1·86
14 atoms oxygen	= 14·000	— — 29·87
	46·875	100·00

I do not understand upon what data Blanchet's calculation of the azote is founded. An analysis of solanina was made by M. Henry, who obtained

Carbon	75·000 or 28	atoms = 21	or per cent.	75·00
Hydrogen	9·142 or 21	atoms = 2·625	— —	9·38
Azote	3·080 or ½	atom = 0·875	— —	3·12
Oxygen	12·778 or 3½	atoms = 3·5	— —	12·50
	100†	26·0		100

The salts of solanina have not hitherto been examined. Its existence in the potatoe after germination is an interesting fact, and should lead to the cautious use of that important vegetable after germination has commenced.

SECTION XVI—OF NARCOTINA.‡

This substance was discovered, in 1803, by Derosne.§ Sertuerner, in 1817, considered it as a meconate of morphina.‖ And this opinion was adopted by Choulant.¶ It was Robiquet who first proved that narcotina and morphina are essentially distinct, and that both are possessed of alkaline properties.**

* Ann. de Chim. et de Phys. liii. 414. † Ann. der Pharmacie, viii. 198.
‡ *Opian* of the Germans. See L. Gmelin's Handbuch der Chimie, ii. 944.
§ Ann. de. Chim. xlv. 257. ‖ Gilbert's Annalen, lv. 56. ¶ Ibid. lvi. 353.
** Ann. de Chim. et de Phys. v. 275.

The easiest method of obtaining it from opium is to digest opium in water,* filter the solution, and evaporate it to the consistence of an extract. Ether digested on this extract dissolves the narcotina, together with some other substances. Distil off the ether and dissolve the residual matter, which is brown and acid, in hot water or boiling alcohol, and digest the solution with animal charcoal. Decant off the clear liquid and precipitate the narcotina by ammonia. If the narcotina thus obtained is not white, it may be dissolved in muriatic acid, and the solution again treated with animal charcoal. The narcotina may be now thrown down by ammonia, washed and dried.

Narcotina obtained by this process is in light white flocks. If we dissolve it in boiling ether or alcohol it is deposited, as the solution cools, in needle-form crystals, collected in bundles, having a pearly lustre, and, in general, more bulky than crystals of morphina.

It does not possess the property of restoring the blue colour of litmus paper reddened by acids; but as it combines with and neutralizes acids we cannot refuse it the appellation of an alkali.

Its taste is not bitter like that of morphina, nor does it strike a blue with the peroxidized salts of iron. When heated it melts, and gives out from 3 to 4 per cent. of water of crystallization. When cooled slowly crystals begin to form in several isolated points, and the whole is converted into a number of hemispherical crystals not attached to each other. When cooled rapidly, the mass remains transparent and gradually cracks.

M. Louis Mialhe de Vabre has shown, that when hyponitrous acid is placed in contact with narcotina, the mixture assumes a carmine-red colour, and gives out red vapours in abundance. In about half a minute the action greatly increases, the narcotina catches fire, and burns with a large white flame. There remains a blackish spongy matter consisting partly of charcoal and partly of bitter principle of Welter, or carbazotic acid.†

It is insoluble in cold water; very little soluble in boiling water; but readily soluble in ether and in fixed oils.

We have three analyses of narcotina, one by Dumas and Pelletier, another by Liebig, and a third by Pelletier. The results are as follows:—

	‡ D. & P.	Liebig.§	Pelletier.‖				per cent.
Carbon	68·88	65·00	65·16	giving 40 atoms =	30	or	64·87
Hydrogen	5·91	5·50	5·45	– 20 atoms =	2·5		5·40
Azote	7·21	2·51	4·31	– 1 atom =	1·71		3·78
Oxygen	18·00	26·99	25·08	– 12 atoms =	12		25·95
	100·00	100·00	100·00		46·25		100

* By this method, however, the whole narcotina is not obtained. Pelletier has shown that the greatest part of it remains in that part of the opium which is insoluble in water. See Ann. de Chim. et de Phys. l. 248.

† Jour. de Pharmacie, xxii. 382.

‡ Ann. de Chim. et de Phys. xxiv. 186.

§ Poggendorf's Annalen, xxi. 29.

‖ Ann. de Chim. et de Phys. l. 271.

Liebig* found that 100 parts of narcotina absorb 9·52 parts of muriatic acid in order to become muriate of narcotina. This corresponds to an atomic weight of 48·5.

The salts of narcotina have been very imperfectly examined. They may be obtained by dissolving narcotina in dilute acids, and concentrating the saturated solution to allow the salts to deposit. Their taste is more bitter than that of the salts of morphina, and they all redden litmus paper.

1. *Muriate of narcotina* is very soluble in water; but it may be obtained in crystals, according to M. Robiquet, by concentrating the solution to the consistence of a syrup and then leaving it on a hot stove. Crystals in radiated groups gradually make their appearance, which increase in quantity, and at last form an opaque mass, composed of fine needles interwoven into each other. When this mass is dried it becomes hard and semitransparent. Still better crystals may be obtained by dissolving muriate of narcotina in boiling alcohol, and allowing the solution to cool slowly.

This salt, according to Liebig, is composed of

1 atom narcotina . . .	48·5
1 atom muriatic acid . .	4·625
	53·125

2. *Sulphate of narcotina* is easily formed, but it cannot be made to crystallize.

From an analysis by Brandes in the *Annalen der Pharmacie* (vol. ii. p. 296), the composition appears to be

Sulphuric acid . . .	5
Narcotina	41·67

But these numbers do not correspond with the preceding analysis.

3. *Acetic acid* dissolves narcotina with facility, but when we attempt to concentrate the solution by evaporation the acid makes its escape. This property is applied to the separation of morphina and narcotina; the acetate of morphina is more stable. If acetate of narcotina exist it is decomposed with the greatest facility.

The remaining salts of narcotina have not been examined.

Narcotina may be introduced into the human stomach without producing any deleterious or even sensible effect. Orfila administered it to the amount of several drams a-day, in various forms, without perceiving any action whatever. When about 2 scruples of it, dissolved in oil, were given to a dog, it was very speedily fatal. Smaller doses kill more slowly, bringing on a stupor from which the animal never recovers. Acetate of narcotina is almost without effect on dogs, the acid having the property of destroying its poisonous qualities.

SECTION XVII.—OF MORPHINA.

Morphina may be obtained from opium by the following process:—Macerate any quantity of opium in twice its weight of water for

* Annalen der Pharmacie, vi. 35.

twenty-four hours, agitating the mixture occasionally to promote the solution. Decant off the solution, and pour over the undissolved portion a new quantity of distilled water, equal to the portion first employed. Repeat this process four times, or till every thing soluble in cold water be taken up. If the opium be of good quality, about three-fourths of it will be dissolved, and the remaining fourth remains in a solid state. Filter the solutions thus obtained, and evaporate the whole to dryness in a low heat, to prevent any portion of the residue from being decomposed or injured. Pour distilled water upon this dry residue. The whole will dissolve except a brilliant crystalline matter, which is *narcotina*. Heat the solution to the temperature of 212°, and add to it ammonia in slight excess. Boil the mixture for ten minutes, to drive off this excess, and then allow the liquid to cool. The morphina precipitates in crystals, pretty pure. But a portion of it swims on the surface, mixed with impurity. If the morphina thus obtained be digested in sulphuric ether, a portion of narcotina is dissolved, and the morphina is rendered more pure. It may be rendered quite pure by dissolving it in boiling alcohol, digesting the solution with some ivory black, filtering and crystallizing. This process should be repeated three or four times, in order to free the morphina of all impurity. An easier mode of purifying it is to dissolve it in sulphuric acid, taking care to avoid adding an excess of the acid. By evaporation the sulphate of morphina is obtained in crystals. Let this salt be decomposed by digesting it with magnesia. The sulphate of magnesia is washed off, and the morphina, which is mixed with the excess of magnesia employed, is to be dissolved in boiling alcohol, and crystallized.

Various other methods of procuring morphina have been proposed, but the preceding appears to be on the whole the easiest. Opium yields at an average about $\frac{1}{16}$th of its weight of pure morphina.

Morphina has a white colour, and is usually crystallized in very small four-sided prisms, sometimes terminated by four-sided pyramids.

Its taste is very bitter and astringent; but it has no sensible smell.

It is insoluble in cold water; but boiling water dissolves about $\frac{1}{100}$th of its weight of it, and allows it to fall in crystals as the solution cools.

It dissolves in 40 times its weight of cold, and 30 times its weight of boiling alcohol. It dissolves also in fixed and volatile oils, and may be fused with camphor. But ether scarcely dissolves it. The crystals are always small. The primary form, according to Brooke, is a right rhombic prism, the faces of which meet at angles of 127° 20′, and 52° 40′. The acute edges are usually replaced by tangent planes, converting the figure into a six-sided prism. The base of the prism is usually concealed by two faces, which meet at an angle of 95° 20′.*

* Brooke, Annals of Philosophy (Second Series), vi. 118.

The transparent crystals of morphina contain, according to Liebig, $6\frac{1}{3}$ per cent. of water. When heated this water flies off, and the crystals become opaque, and white. If we raise the temperature the morphina melts, and forms a yellow liquid, which becomes white, and crystalline when allowed to cool. When still farther heated in contact with the air, it gives out a resinous odour, smokes, and burns with a vivid red flame, giving out much smoke, and leaving a charry residue.

Caustic potash, or soda ley, dissolves morphina. These alkalies, of course, cannot be employed in throwing it down from the infusion of opium. Caustic ammonia dissolves it also, though in much smaller quantity. We ought, therefore, when we employ ammonia to throw down morphina, to take care not to add too great an excess of that alkali.

From the experiments of Pelletier it appears that iodine forms only an ephemeral combination with morphina. When the two are triturated together, a reddish-brown powder is formed, which soon becomes black, the iodine being disengaged, and the morphina altered in its properties. At the same time hydriodic acid is formed.*

When morphina is taken into the stomach in a solid state, it has been found to have but little action, probably on account of its little solubility in water; but when in solution it acts with considerable energy. It has been tried in solution in olive oil and alcohol; but the best solvents are the acids,—acetic acid, muriatic acid, and sulphuric acid, answer very well. When these salts are taken in small doses of from $\frac{1}{4}$ to $\frac{1}{2}$ grain, they act as sedatives. In larger doses they produce the symptoms of intoxication, and occasion deleterious and even fatal effects when given to the amount of 6 or 8 grains.

Morphina has been subjected to analysis by heating it with black oxide of copper, and collecting the products. The following table exhibits the analyses that seem to have been made with the greatest care:—

	Bussy.†	Henry & Plisson.‡	Pelletier & Dumas.§	Brandes.‖	Liebig.¶	Mean.
Carbon	69·0	70·52	72·02	72·0	71·364	71·340
Hydrogen	6·5	7·9884	7·61	5·5	6·559	6·494
Azote	4·5	4·7860	5·53	5·5	4·606	5·131
Oxygen	20	16·7056	14·84	17·0	17·471	17·035
	100·0	100·0000	100·00	100·0	100·000	100·000

If we adopt (instead of the mean) Liebig's analysis, the formula for morphina will be

* Ann. de Chim. et de Phys. lxiii. 185.

† L. Gmelin's Handbuch, ii. 937. ‡ Jour. de Pharmacie, xvii. 453.

§ Ann. de Chim. et de Phys. xxiv. 185.

‖ L. Gmelin's Handbuch, ii. 937. ¶ Poggendorf's Annalen, xxi. 17.

34 atoms carbon	= 25·5	or per cent.	71·83
18 atoms hydrogen	= 2·25	— —	6·34
1 atom azote	= 1·75	— —	4·93
6 atoms oxygen	= 6	— —	16·90
	35·5		100

To determine the atomic weight of morphina, Liebig passed a current of dry muriatic acid over 600 parts of it, till the gas ceased to be absorbed. The muriate thus formed weighed 676 parts, and was perfectly neutral. It was dissolved in water, and the muriatic acid thrown down by nitrate of silver. The chloride of silver obtained weighed 298.*

The atomic weight deduced from the increase of weight of the morphina when saturated with muriatic acid is 36·51

That from the weight of chloride of silver is 36·24

2)72·75

Mean . . . . . 36·375

Liebig, in order to corroborate the accuracy of these experiments, subjected the sulphate of morphina to analysis. It was crystallized, dried in the open air, and then heated in a temperature of 248°, till it ceased to lose weight. The result of his analysis was as follows:—

Morphina . .	75·38	or 36·48
Sulphuric acid .	10·33	or 5
Combined water .	4·66	or 2·25
Water of crystallization	9·63	or 4·66
	100·00	

5 being the atomic weight of sulphuric acid, it is obvious that 36·48 is the atomic weight of morphina. This approaches very near the deduction from the muriate. Indeed, if we assume the composition of the muriate as indicated by the increase of the weight of the morphina, when saturated with muriatic acid (which is most susceptible of accuracy), the two very nearly agree, and give us for the atomic weight of morphina the number 36·5.

It has been observed above that the transparent crystals of morphina contain $6\frac{1}{3}$ per cent. of water. It is obvious from this that they are composed of

1 atom morphina .	36·5	or	94·19
2 atoms water .	2·25	or	5·81
	38·75		100·00

The small excess of water obtained by Liebig was doubtless hygrometrical water.

Many experiments have been made to discover a ready mode of

* Poggendorf's Annalen, xxi. 18.

detecting morphina, and distinguishing it from other bodies. When this alkaline substance, or any of its salts is placed in contact with a neutral solution of a *neutral* salt of peroxide of iron, it strikes a blue colour, as was first observed by M. Robinet. The addition of a slight excess of acid causes this colour to disappear immediately. The addition of too much water causes the blue colour to pass into red.*

Nitric acid changes the colour of morphina into orange-red, which gradually passes into yellow. But as this acid produces the same alteration on brucina and its salts, we cannot depend upon this character.

Serullas pointed out iodic acid as an excellent reagent for detecting morphina. When a solution of iodic acid is brought in contact with a little morphina, or acetate of morphina, the liquid assumes a reddish-brown colour, and exhales the peculiar smell of iodine. A very minute quantity of morphina ($\frac{1}{100}$th of a grain for example) is sufficient to produce a sensible effect. But we must always employ starch to detect the quantity of iodine which is set at liberty.

M. Douné has observed that when morphina is exposed to the vapour of iodine, it assumes a yellow colour, with a shade of brown. The vapour of bromine, on the other hand, gives it an orange-yellow colour.†

Let us now take a view of those salts having morphina for a base, which have been formed and examined.

1. *Muriate of morphina.* This salt is very much employed in Edinburgh as a medicine, and a method of preparing it, first suggested by Dr Robertson, and afterwards improved by Dr Gregory and M. Robiquet, is now in general use, as preferable to every other.‡ This method is as follows:—

The aqueous solution of opium is concentrated in a vessel of tinned iron, to the consistence of a thin syrup, when a slight excess of chloride of calcium, neutral, and quite free from iron, is added. The mixture is boiled for a few minutes, and then poured into an evaporating basin. Resinous flocks, meconate of lime, and colouring matter precipitate. But this last matter does not separate well unless the liquid has been sufficiently concentrated. After this deposit has subsided, the clear liquid is evaporated on the sand-bath. During the evaporation a new deposition takes place, which must be separated before the liquid be allowed to crystallize. The concentrated liquid is now to be allowed to cool, under constant agitation. The crystals of muriate of morphina are deposited in abundance. They are to be put into a stout cloth, and subjected to pressure, which squeezes out a black liquid, containing various impurities.

The crystals are now to be dissolved in water, of the temperature of 70°, filtered through cloth, mixed with a little chloride of calcium, crystallized and compressed as before. These crystals are again

* Jour. de Pharmacie, xiii. 24. † Ann. de Chim. et de Phys. xxxviii. 84.

‡ Edin. Med. and Surg. Journal, Nos. 107 and 111. See also Jour. de Pharmacie, xix. 156.

dissolved in water, the liquid is saturated with chalk, and animal charcoal being added, the whole is digested for twenty-four hours in a temperature of 194°. It is then filtered and concentrated. The crystals are deposited rapidly, and when freed from the mother water they are white and neutral. The salt thus obtained is dried in a temperature of 150°. It usually amounts to about $\frac{1}{10}$th of the weight of opium employed, and consists of muriate of morphina, mixed with a little muriate of codeina; from which it might probably be freed by digesting in ether.

Muriate of morphina crystallizes in needles, or in feather-shaped crystals. It requires from 15 to 20 times its weight of cold water to dissolve it, but it dissolves in less than its own weight of boiling water, and when the liquid cools the whole almost becomes solid by the deposition of crystals.

It dissolves in strong nitric acid, with a weak evolution of gas, and assumes a red colour. Sulphuric acid decomposes it.

2. *Hydriodate of morphina* is a white silky salt, more soluble than the other hydriodates.

3. *Chlorate of morphina* is said to crystallize in regular prisms.

Iodic acid is decomposed by morphina. Of course no such salt as iodate of morphina can exist.

4. *Sulphate of morphina.* This salt crystallizes in needles, usually collected in bundles. It dissolves in about twice its weight of water.

5. *Bisulphate of morphina.* This salt may be obtained by adding sulphuric acid to the neutral salt, and digesting the whole in ether, to remove any excess of acid that may have been added. It has an acidulous taste, and contains just twice the acid in the sulphate.*

6. *Nitrate of morphina.* When dilute nitric acid is saturated with morphina, and the solution evaporated, needle crystals are deposited in stars, soluble, according to Choulant, in $1\frac{1}{2}$ times their weight of water.†

7. *Phosphate of morphina.* The phosphate of morphina, according to Pettenkoffer, crystallizes in cubes. When the salt contains an excess of acid, the crystals are needles connected in bundles.

8. *Acetate of morphina.* Morphina dissolves readily in acetic acid, and when the solution is concentrated, the acetate crystallizes, with difficulty, in short prisms, easily soluble in water, but less soluble in alcohol. This salt is apt to lose a portion of its acid, even when kept in crystals; and during the evaporation crystals of morphina are sometimes deposited.

This salt is employed in medicine on the Continent in preference to every other; but in Edinburgh the muriate of morphina is preferred.

9. According to Choulant, *tartrate of morphina* crystallizes in oblique prisms.§

* Pelletier and Caventou; Ann. de Chim. et de Phys. xii. 122.
† Gilbert's Annalen der Phys. lvi. 348. ‡ Ibid. 348.

10. *Pectate of morphina* may be obtained by digesting pectic acid, still moist with morphina and water. The base and acid dissolve, and the salt precipitates in the state of a jelly when alcohol is poured into the solution.*

11. *Meconate of morphina.* There is reason to believe that it is in combination with meconic acid that morphina exists in opium. But this meconate has never been obtained in the state of crystals; nor indeed have its properties been examined.

12. *Tannate of morphina.* It is a white powder, composed, according to M. O. Henry, of

Tannin . . .	59·81 or 54·31
Morphina . . .	40·19 or 36·5
	100·00†

It is therefore a tertannate.

13. *Kinate of morphina.* Does not crystallize, but forms a gummy transparent mass, dry on the surface, but moist internally.‡

The salts of morphina have been hitherto but superficially examined. They have all a strong, bitter, and disagreeable taste. Their aqueous solutions are precipitated in flocks by the alkaline carbonates. Ammonia produces no precipitation in dilute solutions of these salts when added in excess; or if a precipitate fall, it is again redissolved. They are not precipitated by infusion of nut-galls, unless they contain narcotina.

SECTION XVIII.—OF ATROPINA.

The first attempt to analyze the leaves of the *atropa belladonna*, or *deadly night-shade*, was made by Melandri, in the year 1808.§ He found in them oxalates of lime and magnesia, chloride of potassium, resin, mucus, extractive, and a substance which he called *animal extractive*. Vauquelin examined atropa belladonna, in 1809,‖ and detected albumen, a bitter nauseous substance, to which he ascribed the narcotic properties of this plant, and a number of salts of potash.

In 1819, M. Brandes detected in this plant a vegetable alkaloid, which he distinguished by the name of *atropina*, and the properties of which he described pretty minutely.¶ Succeeding experimenters not being able to obtain this alkaloid by the method described by Brandes, called in question its existence altogether. But M. Runge, in his experiments on *daturina*, an alkaloid exceedingly resembling, if not the very same with atropina, explained the reason of this want of success, by showing that it was decomposed by the caustic alkalies, even when very weak.** Hence it is obvious, that

* Braconnot. † Jour. de Pharmacie, xxi. 221.

‡ Henry and Plisson, Jour. de Pharmacie, xv. 406.

§ Ann. de Chim. lxv. 222. ‖ Ibid. lxxii. 53.

¶ Schweigger's Journal, xxviii. 9. The paper, translated into English, will be found in the Annals of Philosophy (*Second Series*), i. 263. See also Annalen der Pharmacie, i. 68, 230.

** Ann. de Chim. et de Phys. xxvii. 32.

no caustic alkali, how weak soever, should ever be employed in the preparation of atropina. In 1833, atropina was obtained, and its properties examined by MM. Geiger and Hesse.* But M. Mein Göders was the first person who obtained it in a state of purity.†

The process recommended by M. Mein‡ for obtaining atropina from the roots of the atropa belladonna, is as follows:—

Let 80 parts of the roots of belladonna, coming from plants from two to three years of age, be reduced to a very fine powder, and digested with 60 parts of alcohol, of the specific gravity 0·830, for several days. The alcohol is then to be separated by subjecting the matter to strong pressure in cloth. Let an equal quantity of alcohol be poured on the powder, and let the mixture be treated as before. These tinctures being mixed together and filtered, one part of slacked lime is added, and the whole is left in a close vessel for 24 hours, and then filtered. Sulphuric acid is now added, drop by drop, till there is a slight excess. Sulphate of lime precipitates, which must be separated by the filter.

Distil off the half of the tincture or rather more; and add to the residue from 6 to 8 parts of water, and heat till the alcohol be disengaged. Concentrate the liquor with great caution, till it is reduced to one-third of its bulk. When it is cold, add to it, drop by drop, a concentrated solution of carbonate of potash, as long as a precipitate continues to fall.

If the liquid contains much atropina, it usually (after a few hours' rest) assumes the form of a gelatinous mass. Filter, and add more carbonate of potash to the liquid which passes through, till all the atropina be thrown down. The matter left to itself gradually assumes the form of a jelly, and exhibits frequently on its surface, or in the mass, white stars of crystallized atropina. By agitation the gelatinous matter separates from the mother water, which is got rid of by pressing it between folds of blotting paper.

Were we to attempt to wash it in this state a great portion of it would be lost. We must allow it to dry, and then making it into a paste with water, squeeze out that liquor, by placing the paste between folds of blotting paper. The residual matter is now dried, and dissolved in about 5 times its weight of alcohol. Filter the solution, and add from 6 to 8 times its volume of pure water. This addition renders the liquid milky, or at least, it becomes so when the excess of alcohol is evaporated. In 24 hours the atropina will be found deposited in crystals of a light-yellow colour. After washing them in a few drops of water, these crystals are dried upon blotting-paper. We obtain from 1000 parts of the root of belladonna, by this process, about 3 parts of atropina.

Atropina thus obtained has a white colour, and is crystallized in transparent prisms, having a silky lustre. It is destitute of smell. It is soluble in absolute alcohol and in ether, and much more soluble in these liquids when hot than when cold. Cold water dissolves

* Annalen der Pharmacie, v. 43. † Ibid. vi. 67.
‡ Jour. de Pharmacie, xx. 87; or Annalen der Pharm. vi. 67.

about $\frac{1}{300}$th of its weight of it; but it is more soluble in hot water. The solution has a very disagreeable bitter taste, and restores the colour of litmus paper reddened by an acid. When applied to the eye even in a very dilute state, it speedily dilates the pupil, and the dilatation continues for a considerable time.

It is not volatilized at the temperature of boiling water. But at a higher temperature it melts, and is converted into vapours, which are deposited like a coat of varnish. Heated in the open air it melts, gives out empyreumatic vapours, becomes brown, and finally, burns with a yellow flame, and giving out but little smoke.

Chlorine has little action on it. With the acids it combines in definite proportions, and forms salts.

Its constituents, according to the analysis of Liebig,* are as follows:—

Carbon	69·84
Hydrogen	8·14
Azote	7·52
Oxygen	14·50
	100·00

M. Liebig found, that 100 parts of atropina, dried in the air, absorbed 18·9 parts of muriatic acid. The atropina became hot, and melted into a yellow transparent matter, which was completely soluble in water. This experiment gives 24·47 for the atomic weight of atropina. Liebig considers atropina as composed of

22 atoms carbon	= 16·5	or per cent.	71·34
15 atoms hydrogen	= 1·875	— —	8·11
1 atom azote	= 1·75	— —	7·57
3 atoms oxygen	= 3·00	— —	12·98
	23·125		100·00

These atomic proportions make the atomic weight less than that deduced from the muriate of atropina. This, indeed, is generally the case. But the ultimate analysis is susceptible of greater accuracy than that of the salts.

The salts of atropina have been examined by MM. Geiger and Brandes.

1. *Muriate of atropina.* It forms brilliant crystals, which are either cubes or square plates. The salt is soluble in water and alcohol. Composed of

1 atom muriatic acid . .	4·625
1 atom atropina . . .	24·5
	29·125

2. *Sulphate of atropina.* Atropina, when heated with concentrated sulphuric acid, is decomposed and blackens. Dilute sulphuric acid dissolves it without alteration, and the sulphate crystallizes, though

* Ann. der Pharmacie, vi. 66.

the crystals are so small and irregular that their shape has not been determined. The salt dissolves in between 4 and 5 times its weight of water. It is soluble also in alcohol. When exposed to the air, it loses its water of crystallization. When strongly heated, it undergoes decomposition, and becomes black. According to Geiger and Hesse, 100 parts of atropina are just saturated by 13·87 parts of sulphuric acid.* If we consider the salt as a compound of 1 atom acid, and $1\frac{1}{2}$ atom atropina, the atomic weight of atropina will be 24.

3. *Phosphate of atropina.* When atropina is dissolved in phosphoric acid and the solution evaporated, the salt assumes the appearance of gum, which deliquesces when exposed to the atmosphere.

4. *Tartrate of atropina.* When dried, forms a colourless transparent mass, which did not crystallize, but absorbed some moisture from the atmosphere.

Nitric, acetic, and oxalic acids dissolve atropina, and form acicular salts, all soluble in water and alcohol. Nitric acid acts much less powerfully on atropina than on strychnina.†

The action of chloride of gold, slightly acid, when dropt into an aqueous solution of atropina is characteristic. The precipitate at first formed is lemon-yellow; but when allowed to remain for some time it assumes a crystalline structure, and is probably a compound of chloride of gold and muriate of atropina.

The aqueous solution of atropina is precipitated white by the infusion of nutgalls, and isabella-yellow by chloride of platinum.

M. Brandes likewise obtained alkalies from seeds of *hyoscyamus niger* and the *datura stramonium*, to which he gave the name of *hyoscyamina*‡ and *daturina*.§ But these two bodies approach so near atropina in their properties, that I think it likely that a more minute examination will show that they are identical.

There are reasons for believing that the Turks are in the habit of administering preparations of these plants to those individuals whom they wish to render idiots.‖

SECTION XIX.—OF CONICINA.

This is the active principle of *conium maculatum*, or *hemlock;* and is next to hydrocyanic acid, the most virulent poison at present known. Geiger seems to have been the first person who obtained it in a state approaching to purity. A set of experiments proving its alkaline properties, and adding considerably to the facts already known, was published in 1836 by MM. Boutron-Charlard and O. Henry,¶ and considerable light has been thrown upon its action

* Annalen der Pharmacie, vi. 52.

† Brandes, Annals of Philosophy (Second Series), i. 264.

‡ Schweigger's Jour. xxviii. 91, and Annalen der Pharmacie, i. 333.

§ Jour. de Pharmacie, vi. 47, and 250. See also Geiger and Hesse, Ibid. xx. 94; and M. Bley, Annalen der Pharmacie, iii. 135.

‖ Jour. de Pharmacie, xx. 117. ¶ Ann. de Chim. et de Phys. lxi. 337.

on the animal economy, by Dr. Christison of Edinburgh, in a paper published in the 13th volume of the *Transactions of the Royal Society of Edinburgh.*

According to Brandes,* it may be obtained in the following manner :—

Digest fresh hemlock in alcohol, add magnesia, or hydrate of alumina, or hydrate of lead to the solution, and distill off the alcohol. Evaporate the residual liquid to dryness on the vapour-bath. Treat the residual matter with a mixture of alcohol and ether, which will take up the *conicina.* Evaporate this solution to dryness, and digest the residue in ether. When the ether is evaporated, it leaves an extractive substance of a light yellowish-brown colour, and a disagreeable smell.

Giesecke, in order to obtain conicina, mixes the expressed juice of conium with magnesia, and distils. The ammoniacal liquid which comes over is neutralized with sulphuric acid, and evaporated to dryness by a gentle heat. The dry residue being digested in absolute alcohol, the conicina is dissolved, while the sulphate of ammonia remains.

Conicina thus obtained gives a flesh-coloured precipitate with tincture of iodine. It is precipitated of a dirty-white colour, by acetate of lead, nitrate of mercury, and nitrate of silver. Tannin throws it down brown. A grain of it was sufficient to kill a rabbit.

Geiger succeeded in isolating from hemlock, a volatile alkaline poisonous substance (doubtless true conicina), by the following process :—

Mix fresh hemlock with potash and water, and distil as long as what comes over has any smell. Neutralize this product with sulphuric acid, evaporate to the consistence of a syrup, and dilute it with anhydrous alcohol, as long as sulphate of ammonia continues to separate. Separate the liquid portion from this salt, distil off the alcohol, mix the residue with very strong potash ley, and distil anew. The alkaline substance conicina passes along with the water into the receiver. It has the form of a yellowish-oil, has a strong smell analogous at once to that of hemlock and of tobacco, and an exceedingly acrid and bitter taste. It is soluble in water, and combines with and neutralizes the acids. It even smokes slightly like ammonia when brought near the volatile acids. It possesses marked alkaline properties, and neutralizes acids. It is poisonous, and so are its salts, but in a less degree. The sulphate of conicina does not crystallize.

It undergoes an alteration by exposure to the air, both when uncombined and when united to acids. When saturated with an acid it assumes a red-colour, which the alkalies destroy.

Boutron-Charlard and Henry succeeded in freeing conicina from ammonia, with which it is at first mixed, by washing it in distilled water. Thus purified it had the following properties :—

* Br. Arch, xx. 111.

It has the appearance of yellowish liquid oil. It dissolves completely in alcohol and ether. It is lighter than water, and is slightly soluble in that liquid. Its smell is strong and penetrating, and recalls at once that of hemlock and of tobacco. Its taste is acrid and corrosive, and it occasions death almost as rapidly as prussic acid. A single drop put into the eye of a rabbit, killed it in nine minutes. Three drops used in the same way, killed a strong cat in a minute and a half. Five drops poured into the throat of a small dog began to act in thirty seconds, and in as many more, motion and respiration had entirely ceased.

MM. Boutron-Charlard and Henry found conicina possessed of decided alkaline characters. It dissolves in the acids, and is capable of neutralizing them. With sulphuric, phosphoric, nitric, and oxalic acids, it forms salts, which crystallize in prisms of a considerable size. During the saturation of these acids, the liquids assume a bluish-green colour, which gradually passes into reddish-brown; and when these salts are evaporated, whether by means of a gentle heat, or by placing them *in vacuo*, over sulphuric acid, they lose a part of their base, as happens with the ammoniacal salts. The salts of conicina absorb moisture from the atmosphere very rapidly, and they are soluble in alcohol.

When conicina is placed *in vacuo*, along with substances which rapidly absorb moisture, it is partially volatilized, and leaves a reddish pitchy-like matter, very acrid, and which Boutron-Charlard and Henry consider as anhydrous conicina. The vapour of conicina is inflammable. It occasions white fumes when placed near a glass rod dipt in muriatic acid.

When the salts of conicina are dissolved in water, they give, with pure tannin, a white curdy precipitate, soluble in alcohol, and very bulky. Conicina, dissolved in alcohol of the specific gravity 0·871, gives, with iodic acid, a copious white precipitate, similar to that which the same acid forms with quinina, cinchonina, strychnina, and brucina.

It appears, from a note to Boutron-Charlard and Henry's paper,* that conicina has been analyzed by M. Liebig, who obtained

Carbon	66·91	or 12 atoms =	9	or per cent.	66·67
Hydrogen	12·00	or 14 atoms =	1·75	— —	12·96
Azote	12·80	or 1 atom =	1·75	— —	12·96
Oxygen	8·29	or 1 atom =	1	— —	7·41
	100·00†		13·5		100

SECTION XX.—PARILLINA.

This alkali was detected by Pallotta, in 1825, in the root of *smilax sarsaparilla*, or the common *sarsaparilla* of the shops.‡ His process was as follows :—

* Ann. de Chim. et de Phys. lxi. 346. † Poggendorf's Annalen, xxxvii. 30.
‡ Brugnatelli's Giorn. xvii. 386, and Jour. de Pharmacie, x. 543.

The roots, reduced to powder, were boiled with six times their weight of water, and the decoction was repeated with fresh water till every thing soluble was taken up. These decoctions were filtered and mixed with a quantity of milk of lime, with which they were frequently agitated till they acquired alkaline properties. The grey precipitate obtained in this way was washed and dried, and boiled for two hours with alcohol of the specific gravity 0·817. This process was repeated with fresh alcohol till every thing soluble was taken up. The alcoholic decoctions were filtered, distilled, and the residual matter left at rest till the parillina was deposited.

Parillina thus obtained is a white powder, not altered by exposure to the air. It has a peculiar smell, and a bitter and sharp taste, slightly astringent and nauseous. It is precipitated from its solutions by chloride of calcium and by the mineral acids.

It gives a brown colour to turmeric paper, fuses when heated to 257°, becomes black, and is partly decomposed. When placed upon a red hot iron plate it behaves like a substance destitute of azote. Concentrated sulphuric acid decomposes it.

It is insoluble in cold and but little soluble in hot water. It dissolves in alcohol. It neutralizes dilute sulphuric acid and other acids, and forms salts. It is only slightly soluble in cold alcohol, but it dissolves readily in boiling alcohol.

Parillina was analyzed by M. Christian Petersen, who obtained

Carbon	62·80 or 9 atoms	= 6·75	or per cent.	62·79
Hydrogen	9·14 or 8 atoms	= 1	— —	9·30
Oxygen	28·06 or 3 atoms	= 3	— —	27·91
	100·00*	10·75		100·00

Pallotta tried the effects of parillina upon himself. When swallowed to the extent of 13 grains it occasioned nausea, vomiting, diminished the rapidity of the pulse, and acted as a sudorific. It is obvious from this that it is a debilitant.

Falchi states that if the pith of sarsaparilla be macerated in water, and the solution, after having been treated with ivory-black and filtered, be left to spontaneous evaporation, small light-yellow crystals separate, which are slightly soluble in alcohol, have but little taste, yet leave a strong impression in the throat, and give a green colour to syrup of violets. To this substance he has given the name of *smilacina*.† Its properties have scarcely been examined.

SECTION XXI.—OF MECONIN.

Meconin differs from all the preceding alkaline bodies, except parillina, in containing no azote. On that account I think it doubtful whether it be really an alkali. This has induced me to leave to it the name *meconin*, by which it is known on the Continent, and to place it at the end of the analyzed alkaline bodies.

* Ann. der Pharmacie, xv. 74. † Berzelius, Traité de Chimie, v. 188.

It was discovered by M. Dublanc, junior, in 1826. It was afterwards discovered anew by M. Couerbe, in 1830, who was unacquainted with the previous examination of it by Dublanc.* It may be extracted from opium in the following manner :—

Cut the opium into small pieces, and digest it in cold water till that liquid ceases to acquire any colour from it. Filter the aqueous solution and concentrate to the specific gravity of 1·05. Add ammonia, previously diluted with 5 or 6 times its weight of water, as long as a precipitate continues to fall. This precipitate is complex, but consists chiefly of morphina. Decant off the liquid portion after a few days, and wash the precipitate with water as long as the liquid continues to be coloured.

All these liquids being mixed are to be evaporated in a gentle heat, to the consistence of a syrup, and left in a cool place for 14 or 15 days. A crop of granular crystals is gradually deposited. Decant off the liquid portion, and dry the crystals, after they are as well freed from the mother water as possible, in a gentle heat, having previously subjected them to pressure between folds of blotting paper.

The crystalline mass obtained is brown or fawn-coloured. Besides meconin it contains some other substances, particularly narceina. Digest it in boiling alcohol, of the specific gravity 0·837, till every thing soluble be taken up. Distil off the alcohol till the solution be reduced to one-third of its original bulk. On cooling, it deposits a quantity of crystals which contain meconin. By farther concentration more of these crystals may be obtained.

Subject these crystals to the press. Dissolve them in boiling water, digest the solution with animal charcoal, and filter. The crystals now deposited from the solution are nearly white; but they still contain narceina. Treat them with ether, which dissolves only the meconin. By spontaneous evaporation, meconin is deposited from this liquid in a state of purity.

Opium yields about $\frac{1}{2000}$th of its weight of meconin.

Meconin is white and destitute of smell. When first put into the mouth it has no taste, but soon imparts an impression of acridity. It is soluble in water, alcohol, and ether, and crystallizes very well from all these solutions. The crystals are six-sided prisms, terminated by dihedral summits.

When heated to 194° it melts, and assumes the form of a colourless limpid fluid. At 311° it may be distilled over without any alteration, and, on cooling, concretes into a hard mass having the aspect of tallow.

It requires $265\frac{3}{4}$ times its weight of cold water, and only $18\frac{1}{2}$ times its weight of boiling water to dissolve it, as determined by the experiments of Couerbe. When digested in water the liquid becomes opaline as it heats, the crystals lose their shape and swim in

* Ann. de Chim. et de Phys. l. 253, and 337.

flocks upon the surface of the water. When the heat approaches the boiling point of water the meconin assumes the appearance of colourless drops of oil, which gradually dissolve.*

Sulphuric acid, diluted with half its weight of water, dissolves it without the assistance of heat. If we heat the solution, even gently, the meconin is altered; green streaks make their appearance, and, in a short time, the whole liquid assumes a fine deep-green colour. If we now mix it with alcohol it becomes rose-red; but when the alcohol is driven off by heat, the green colour again appears. Water throws down from the solution a brown flocky matter, which does not redissolve in the dilute acid, even when assisted by heat. But it is dissolved by concentrated sulphuric acid when assisted by a gentle heat, and the solution is green. It is insoluble in water, but easily dissolved by alcohol and ether, to which it communicates a deep-red colour.

Acetate of lead, when dropt into a solution of meconin, occasions no precipitate; but the diacetate throws it down, and forms with it a kind of chemical compound.

Potash and soda dissolve meconin, but do not appear to form a chemical compound with it. Ammonia does not dissolve it, and carbonate of ammonia throws it down from its solution in caustic potash or soda.

When treated with nitric acid crystals are obtained which possess the characters of an acid, and which M. Couerbe, who discovered it, has distinguished by the name of *hyponitromeconic acid.*

When a current of chlorine gas is passed over meconin in fusion, the gas is absorbed, and a substance is formed at first red and then deep-yellow. By this action two distinct substances are formed. The first is white and crystallizable, and has been distinguished by M. Couerbe, who discovered it, by the name of chloride of *mechloic acid.* The other substance has a resinous aspect and a yellow colour, contains much chlorine, and may be separated by boiling the product with carbonate of soda.

Meconin does not possess alkaline properties, and does not seem capable of combining in definite proportions with acids. Its crystals contain no water of crystallization, for they may be kept in fusion for any length of time without any loss of weight. We are therefore ignorant of the atomic weight of this substance. But it contains no azote, and when subjected to analysis by Couerbe he obtained from 1 part of meconin 2·241 parts of carbonic acid and 0·462 parts of water. This gives for its constitution, per cent.

Carbon	61·03	or 10 atoms	= 7·5	or per cent.	61·86
Hydrogen	5·13	or 5 atoms	= 0·625	— —	5·15
Oxygen	33·84	or 4 atoms	= 4·0	— —	32·99
	100·00†		12·125		100·00

* Ann. de Chim. et de Phys. l. 339. † Ibid. lix. 140.

Hence 12·125, or some multiple of this number, must represent the atomic weight of meconin.

CHAPTER II.

ALKALIES IMPERFECTLY EXAMINED.

These at present amount to 16, and doubtless will increase very much as the vegetable kingdom comes to be more thoroughly examined.

SECTION I.—OF JERVINA.

M. Simon has given this name to an alkaline substance which he has extracted from the roots of the *veratrum album*, the same plant from the seeds of which the veratrina had been extracted by Pelletier and Caventou. Hitherto its characters have been but imperfectly investigated.*

The alkaline extract of the root was repeatedly boiled with water acidulated with muriatic acid, and the filtered decoction precipitated by a solution of carbonate of soda. Care must be taken that no admixture of sulphate of soda be present. The precipitate is dissolved in alcohol, and the solution deprived of its colour by animal charcoal. The alcohol is then nearly separated by distillation. The residue, on cooling, crystallizes in stars. These crystals are subjected to pressure, by which means they are separated from the greatest part of the uncrystallized veratrina present. The expressed mass is again moistened with alcohol and subjected to pressure a second time. This renders the jervina quite pure.

The expressed liquid contains both veratrina and jervina. Let it be evaporated to dryness, and let the residue be boiled with dilute sulphuric acid. The jervina forms with this acid a very little soluble salt, while the sulphate of veratrina is very soluble. Hence the former precipitates, while the latter remains in solution. By boiling the sulphate of jervina with carbonate of soda it is decomposed and the jervina† obtained.

Jervina forms with sulphuric, nitric, and muriatic acids, salts very little soluble in water. Of these the sulphate is the least soluble. An excess of acids does not render the salts more soluble. When sulphate of jervina is boiled in a great deal of water, solution takes place, but the salt is again precipitated as the solution cools. Acetic and phosphoric acids form with jervina very soluble salts. The base

* Poggendorf's Annalen, xli. 569.

† Named by Simon from *Jerva*, which, according to Casper Bauhin, is the name given by the Spaniards to the poison of the white hellebore.

is precipitated from these solutions by the addition of either of the three first-mentioned salts.

Alcohol dissolves the difficultly soluble salts of jervina; but they are not so soluble in that liquid as the salts of the other vegetable alkaloids.

SECTION II.—OF DIGITALINA.

Le Royer announced, in 1824,* that if the dried leaves of the *digitalis purpurea*, or fox glove, be digested in ether, and the solution afterwards concentrated by distilling off the ether to the consistency of an extract, water dissolves from this extract an acid salt, having a peculiar alkaloid basis, to which the name of *digitalina* has been given, and leaves a green fecula. The acid salt is treated with oxide of lead, the solution is then evaporated to dryness, and the dry residue digested in ether, which leaves the salt of lead, but dissolves the digitalina. When the ether is driven off the digitalina remains in the form of a brown butter-looking substance, having an acrid taste, and acting weakly as an alkali upon litmus paper, reddened by an acid. When dissolved in alcohol, and dried on a glass plate, it forms microscopic crystals, which speedily absorb moisture from the atmosphere. This process was examined by Brault and Poggiale, who found the digitalina of Le Royer a mixture of chlorophylle, resin, fatty matter, and some salts of lime and potash.†

According to Planiava, we may obtain a great quantity of digitalina by digesting in ether the extract of digitalis made by water, till every thing soluble is taken up. The etherial solution is mixed with water, and distilled. The water dissolves the digitalina, while a little chlorophylle separates. Mix the aqueous solution with oxide of lead in fine powder, and evaporate to dryness in a gentle heat. Digest the residue in ether. The digitalina will be dissolved, and will remain, when the ether is evaporated, in the state of a light-yellow matter, without the least appearance of crystallization.‡ But this process was tried by Brault and Poggiale without any satisfactory result.§ Another process has been given by Lancelot.‖ And Dr David found that the digitalina extracted by his process possesses the properties of the plant.

Digitalina has not yet been obtained in an isolated state. It is obviously very soluble in water, and soluble also in alcohol and ether. It is poisonous, and exerts the same action on the animal economy as digitalis itself. When from $\frac{1}{2}$ to $1\frac{1}{2}$ grains of it is injected into the veins of an animal, death speedily ensues, without convulsions, and with the same effect upon the pulse which characterizes digitalis.

Digitalina does not give out ammonia when distilled. Its

* Bibliotheque Univ. xxvi. 102.
† Jour. de Pharmacie, xxi. 130.
‡ Berzelius, Traité de Chimie, vi. 277.
§ Jour. de Pharmacie, xxi. 130.
‖ Ann. der Pharm. xii. 251.

aqueous solution is precipitated by diacetate of lead, and by the infusion of nutgalls. No attempts have been made to analyze digitalina, nor is it likely that hitherto it has been obtained in a state of purity.

M. Dulong d'Astafort examined this substance in 1826. It was bitter, would not crystallize, contained no azote, and did not possess the properties of a base.*

SECTION III.—OF NICOTINA.

This alkali exists in the leaves and seeds of the different species of tobacco; namely, *nicotiana tabacum*, and *nicotiana rustica*. The experiments of Vauquelin showed its existence in these plants.† Hermbstadt afterwards obtained nicotina in a state of tolerable purity.‡ But it was Posselt and Reimann that first examined it, and ascertained its characters with accuracy.§ It may be extracted in the following manner:—

Boil 12 lbs. of dried tobacco leaves in water, acidulated with sulphuric acid. Evaporate the decoction to dryness in a gentle heat, and digest the residual matter in alcohol, of the specific gravity 0·848. Distil off the greatest part of the alcohol from this solution, and mix the residue with hydrate of magnesia or slacked lime. Then distil again. The product of this distillation is water, containing in solution nicotina and ammonia. By agitating it with ether a portion of the nicotina is dissolved in the ether. The aqueous portion separated from the ether is poured back upon the residual matter in the retort, and distilled again. The distilled liquid agitated again with ether gives to it an additional portion of nicotina. These distillations and agitations with ether are to be continued till the residue in the retort has lost its acridity, and is distinguished only by a bitter taste.

The etherial solutions are deprived by chloride of calcium of the water which they contain. And the liquid being decanted off, is distilled by a gentle heat. The ether passes over into the receiver, while the nicotina does not begin to rise till the temperature be raised to 212°.

Nicotina obtained in this way has the consistence of honey, an acrid taste, and a brown colour. To obtain it perfectly pure it must be distilled in an oil-bath, at the temperature of 284°.

MM. O. Henry and Boutron-Charlard obtained it by the following process:—

A pound avoirdupois of tobacco, together with 332 cubic inches of water, and $6\frac{4}{10}$ ounces avoirdupois of caustic soda were put into a cucurbite. A moderate heat was first applied, and then the liquid was made to boil. What distilled over was received into a glass vessel, containing rather more than an ounce of sulphuric acid, diluted with three times its weight of water. When about 150 cubic

* Jour. de Pharmacie, xiii. 379.
† Ann. de Chim. lxxi. 189.
‡ Schweigger's Jour. xxxi. 442.
§ Mag. Pharm. xxiv. 138.

inches have passed over, the process is stopped. The product (which must be kept slightly acid) is evaporated down to about 1500 grains. It is then allowed to cool, to separate a small deposit. It is to be filtered, mixed with an excess of caustic soda, and distilled in a small retort. A colourless volatile liquid is obtained, which is concentrated *in vacuo* to the consistence of a syrup. This matter has an amber colour, and gradually deposits small crystalline plates, constituting nicotina.*

The crystals soon absorb moisture, and form a transparent, almost colourless liquid. Its smell, while cold, is almost nothing, but that of its vapour is similar to that of tobacco, acrid and disagreeable; and its taste is acrid and caustic, and continues long in the mouth. It remains liquid though cooled down to 21°. It restores the colour of litmus paper, reddened by an acid, and renders turmeric paper brown. When heated to 212° it gives out a white smoke, which tinges turmeric paper brown. At 375° it boils, and at the same time undergoes decomposition, becoming brown, assuming the appearance of resin, and losing its acrid qualities. Even at the ordinary temperature of the atmosphere, the air acts upon it, communicating a brown colour, and inducing inspissation and partial decomposition. It is difficult to make it burn with flame without using a wick. It then burns, giving a strong flame, and emitting much smoke.

Water dissolves it in all proportions. Ether dissolves it also with facility, and when agitated with water, deprives that liquid of a great part of the nicotina which it holds in solution. Oil of turpentine dissolves a little of it. It is soluble also in almond oil; when acetic acid is mixed with this solution it separates the nicotina. The alcohol solution of iodine destroys it, giving it at first a yellow, and finally a red colour. Its specific gravity is 1·048. When cautiously heated in a platinum capsule, it may be volatilized in a white irritating vapour, without leaving any residue. This vapour catches fire at the approach of an ignited body. It contains a much greater proportion of azote than any of the other vegetable alkaloids. It has not been analyzed; but its atomic weight is about 26·25.

Nicotina acts with great violence on the living body, being a most virulent poison. A single drop of it is sufficient to kill a moderate-sized dog. It possesses alkaline qualities, and neutralizes acids.

The salts of nicotina are distinguished by their taste of tobacco, and their acrid causticity. They are colourless, and generally soluble in water and alcohol; but they do not seem to be soluble in ether.

1. *Sulphate of nicotina.* One part of common sulphuric acid requires $4\frac{2}{3}$ parts of anhydrous nicotina to saturate it. The salt crystallizes with difficulty in plates. It has no smell, and is soluble in alcohol.

2. *Phosphate of nicotina.* It crystallizes, when concentrated to

* Jour. de Pharmacie, xxii. 692.

the consistence of a syrup, in plates, having some resemblance to cholesterin.

3. *Acetate of nicotina.* This salt forms an incrystallizable syrup. When it is mixed with corrosive sublimate, or chloride of platinum, a double salt is formed, which precipitates, being but little soluble in water.

4. *Oxalate of nicotina.* A very soluble and crystallizable salt.

5. *Tartrate of nicotina.* It is very soluble, and crystallizes in grains, the shape of which it is not easy to discover.

The following are the effects of reagents on the aqueous solution of nicotina, as determined by Henry and Boutron-Charlard :—

1. Protosulphate of iron, a greenish precipitate, passing into ochre red.
2. Sulphate of copper, a greenish-white precipitate, not redissolved by an excess of nicotina.
3. Phosphate of magnesia, a gelatinous precipitate.
4. Perchloride of iron, a brick-red precipitate.
5. Sodium chloride of gold, a copious orange precipitate.
6. Chloride of platinum, a yellowish granular precipitate.
7. Sulphate of zinc, a flocky precipitate.
8. Corrosive sublimate, a copious curdy precipitate.
9. Tartar emetic, a white precipitate.
10. Sulphate of manganese, white flocks.
11. Acetate of lead, a white precipitate.
12. Nitrate of silver, and cyanodide of mercury, O.

The following table exhibits the quantity of nicotina yielded by 1000 parts of various kinds of tobacco :—

Cuba	8·64
Maryland . . .	5·28
Virginia . . .	10·00
Ile de Vilain . . .	11·20
Lot	6·48
North	11·28
Lot-et-Garonn . .	8·20
For smoking . . .	3·86

SECTION IV.—OF CURARINA.

This alkali was discovered, in 1828, by Boussingault and Roulin,* in a substance used by the Indians of South America to poison their arrows, and which is distinguished by the name of *curara*, or *urari*. Humboldt informs us that it is extracted by water from a species of strychnos, called in South America *mava cure*. The aqueous extract is mixed, to give it consistence, with the mucilaginous extract of another plant. Curara may be taken into the stomach with impunity, but when introduced into a wound it occasions death in a few minutes. The experiments of Boussingault and Roulin were repeated, and confirmed, in 1829, by Pelletier and Petroz.† Curarina was obtained in the following manner :—

* Ann. de Chim. et de Phys. xxxix. 24. † Ibid. xl. 213.

The *curara* was reduced to powder, and boiled in alcohol. The tincture being mixed with a little water, the alcohol was distilled off. The aqueous residue was decanted off a resinous precipitate which had fallen. It was digested with ivory black, and then precipitated by infusion of nutgalls. The precipitate, which was brown-coloured, and bitter tasted, consisted of a combination of tannin and curarina. It was washed with a little water, heated to the boiling temperature, and then mixed by little and little with crystals of oxalic acid till the whole was dissolved. The acid liquor was treated with magnesia, which united both with the oxalic acid and the tannin, while the curarin remained in the solution. It was evaporated to dryness, and the dry residue was treated with alcohol, which left undissolved a small quantity of oxalate of magnesia. The alcoholic solution was evaporated, and the curarina dried *in vacuo* by means of sulphuric acid.

Curarina thus obtained constitutes a yellow-coloured, horny-looking substance, which is transparent when in thin plates, but has not the least tendency to form crystals, and which deliquesces when exposed to the air. Its taste is very bitter. When heated it is charred, and gives out the odour of burning horn. It is very soluble in water and alcohol; but it is insoluble in ether and oil of turpentine. It restores the blue colour of litmus paper reddened by an acid, and gives a brown colour to turmeric paper.

It combines with acids, and forms neutral salts, having a bitter taste. The muriate, sulphate, and acetate of curarina, the only ones hitherto examined, are incrystallizable. Tannin alone, of all the reactives tried, has the property of throwing down curarina from its solutions. It is still a more active poison than the curara from which it was obtained.

SECTION V.—OF CORYDALINA.

This alkali was detected by M. Wackenroder, in the root of the *corydalis tuberosa*, or *fumaria bulbosa*.* It may be extracted in the following way :—

The root, reduced to a coarse powder, is to be macerated in water for some days; a deep-red infusion is obtained, which reddens litmus paper. Let it be filtered, and mixed with as much alkali as will render it slightly alkaline. A grey-coloured precipitate falls, which is to be collected on a filter. The root remaining is subjected to a new maceration in water, acidulated with sulphuric acid, which dissolves a new quantity of corydalina. It is to be thrown down by an alkali, but not mixed with the former precipitate, because it is more difficult to purify. Let the precipitate be dried, and boiled in alcohol till every thing soluble has been taken up. Distil off the greatest part of the alcohol from this solution. Sometimes the residual liquid, on cooling, deposits a little corydalina in crystals. Evaporate the liquid to dryness, and pour on the

* Kastner's Arch. viii. 417.

residual matter very dilute sulphuric acid, which dissolves the corydalina, and leaves the green resinous matter. Precipitate the solution by an alkali, taking care to separate the dark-coloured matter which falls first, because it is impure matter. This being removed, the alkali throws down the corydalina white; but it assumes a shade of grey while washing. When dry, it is a greyish-white incoherent mass, which stains the fingers.

It has no smell, and little taste. It is very soluble in alcohol, and the more so the freer it is from water. The colour of the solution is greenish-yellow. Alcohol, when saturated with corydalina at the boiling temperature, lets fall, on cooling, colourless prismatic crystals, about a line in length. By spontaneous evaporation corydalina crystallizes in scales.

The alcoholic solution of corydalina changes the colour of litmus, red cabbage, and roses, in the same manner as an alkali does. When exposed to the action of solar light, corydalina becomes deeper coloured, and assumes a greenish-yellow tint; and this change takes place more rapidly when the alkaloid is in the state of powder, than when in crystals. It melts when heated to 212°. The fused mass is translucent when in thin coats, and yields a crystalline fracture. If the temperature be elevated it becomes brown, gives out water and ammonia, and assumes the form of a brown translucent mass.

It is very little soluble in water, but is easily held in suspension in that liquid by occasional agitation. When boiled with water it melts, and rises under the form of greenish-yellow drops, which swim upon the surface of the liquid. During the cooling the water becomes muddy, because part of the corydalina is deposited. Ether dissolves corydalina with facility. Caustic alkalies are better solvents than water, and the solution has a greenish-yellow colour. We must, therefore, beware of adding too much alkali when we precipitate this alkaloid from its solution in an acid.

No attempt has hitherto been made to analyze corydalina. The salts which it forms with the acids have a bitter taste.

1. *Muriate of corydalina.* Obtained by dissolving corydalina in muriatic acid. When the solution is evaporated to dryness, an incrystallizable salt remains, which is soluble in water, alcohol, and ether.

2. *Sulphate of corydalina.* When an excess of base is digested with dilute sulphuric acid, the liquid deposits, when concentrated by evaporation, a crystallized salt, which is but little soluble in water. If to an alcoholic solution of corydalina we add a little sulphuric acid, so as not to supersaturate the base, and then evaporate the liquid, we obtain, in the first place, the crystallized salt. The mother water being afterwards evaporated to dryness, yields a translucent mass of a greenish-yellow colour, having the appearance of gum, not altered by exposure to the air, and very soluble in water. It reddens litmus paper. When there is an excess of concentrated sulphuric acid present, the base is destroyed.

3. *Nitrate of corydalina.* Nitric acid destroys corydalina, and gives it a red colour when the liquid is concentrated. This reaction is so sensible, that nitric acid, heated with a liquid containing corydalina, detects the most minute quantity of that base.

4. *Acetate of corydalina.* Concentrated acetic acid dissolves corydalina much more slowly than the mineral acids. When the solution is evaporated we obtain the acetate of corydalina in crystals. This salt is very soluble in water.

Corydalina is precipitated from its solutions by infusion of nutgalls, which constitutes an excellent reagent for detecting it.

SECTION VI.—OF JAMACINA.

This alkali was discovered in 1824, by M. Hüttenschmidt,* in the bark of *geoffroya jamaicensis;* the *geoffroya inermis*, or *cabbage bark tree* of Dr Wright. It was obtained by the following process:—

Boil the bark repeatedly in alcohol of the specific gravity 0·832, and distil off the alcohol from the filtered decoctions. Dissolve the residue in water, and filter the solution. Mix it with acetate of lead as long as any precipitate falls, and throw down the excess of lead by a current of sulphuretted hydrogen gas. Filter the liquid, and add a little sulphuric acid to it. Sulphate of jamacina falls in small grains. Concentrate the residual liquid till as many of these crystals as possible are obtained. Dissolve the sulphate of jamacina in water, and digest the solution with carbonate of barytes till all the sulphuric acid is abstracted. Filter the liquid while boiling hot, and concentrate the solution till the jamacina is deposited in crystals.

These crystals are four-sided tables, translucent, and lemon-yellow. They undergo fusion at 212°, have a very bitter taste, and seem to possess purgative qualities. They dissolve readily in water, and the colour of the solution is lemon-yellow. The aqueous solution gives a yellow precipitate, with tincture of nutgalls. Jamacina dissolves also in alcohol.

It possesses alkaline properties, as it dissolves in acids, and forms salts. The muriate, sulphate, nitrate, and phosphate, crystallize. They have a bitter taste, and a yellow colour, are soluble in water and alcohol, and burn when sufficiently heated.

The *nitrate of jamacina* has a yellow colour. It melts, when heated, rather under 212°. Sulphuric acid drives off the nitric. It dissolves better in water than in alcohol.

Oxalate of jamacina is obtained by saturating the aqueous solution of jamacina with oxalic acid. The salt is gradually deposited in crystals.

The *acetate of jamacina* is obtained by the process above described for the preparation of jamacina. After the excess of lead

* Disser. sist. Analys. Geoffroyæ Jamaicensis et Surinam, as quoted by L. Gmelin; Handbuch der Chemie, ii. 908.

has been thrown down by sulphuretted hydrogen, the solution is to be evaporated to dryness, without the addition of sulphuric acid. The residue is to be washed with a little cold alcohol, and purified by dissolving it in water, filtering the solution, and evaporating it. Yellow bitter-tasted tables are deposited, which melt at a temperature lower than 212°, and then take fire and burn, giving out the odour of acetic acid. This salt is very soluble in water, and less soluble in alcohol.

SECTION VII.—OF SURINAMINA.

This alkali was discovered in 1824, by M. Overduin, in the bark of the *Geoffroya Surinamenis*, another species of the same genus, which grows in Surinam, and the account of it was published at the same time.* It was discovered also by M. Hüttenschmidt, who described its mode of preparation and its properties, in his inaugural dissertation. M. Van der Byll is of opinion that Hüttenschmidt's alkali was nothing else than sulphate of alumina. But this is not likely.

To prepare *surinamina*, digest the bark in alcohol, and from the alcoholic solution distil off the spirit. Digest the remaining extract in water, and mix the solution with acetate of lead. Filter, and throw down the excess of lead by sulphuretted hydrogen gas. Filter again, and then evaporate the solution. A portion of the surinamina precipitates. The rest may be obtained by digesting the liquid with magnesia, filtering, and farther evaporation.

Surinamina thus obtained is in bulky, woolly-looking needles. Its colour is white, its taste not strong, but disagreeable, and when given to the extent of two grains it had no effect upon a pigeon. It is but little soluble in cold, though moderately soluble in hot water. The aqueous solution is not altered by iodine, ammonia, nitrated suboxide of mercury, nor tincture of nutgalls.

In hot alcohol it is less soluble than in water. In dilute sulphuric acid it dissolves with facility. The solution is light-red, tastes like sulphate of magnesia, and yields crystals.

When surinamina is heated in a glass tube, it gives out first a smell resembling bruised plums, and at last exhales a vapour, having the smell of ammonia, and leaves a bulky charcoal. When it is dissolved in nitric acid the solution is at first violet, and then Berlin-blue. In 48 hours the colour vanishes, and violet-coloured flocks are precipitated.

SECTION VIII.—OF CATHARTINA.

The examination of the leaves of *cassia acutifolia*, or common *senna*, was begun by Bouillon Lagrange,† and prosecuted still farther by Braconnot. But it was Lassaigne and Feneulle, who in 1821 extracted from them the cathartic principle, to which they are indebted for their introduction into medicine.‡ This principle, to

* Ann. der Pharmacie, vii. 265. † Ann. de Chim. xxvi. 3.

‡ Ann. de Chim. et de Phys. xvi. 16.

which they give the name of *cathartina*, was obtained in the following manner :—

The decoction of the dried leaves of senna was precipitated by acetate of lead, and the filtered solution treated with sulphuretted hydrogen, to throw down any excess of lead that may have been added. The liquid was now evaporated to dryness, and the residue treated with alcohol which dissolved the cathartina, together with some acetate of potash. The alcoholic solution was distilled till it was brought to the consistency of an extract and then mixed with alcohol containing some sulphuric acid, in order to throw down the potash in the state of sulphate. The liquid was now filtered to separate the sulphate of potash. The excess of sulphuric acid was thrown down by acetate of lead, and the excess of lead by sulphuretted hydrogen. Nothing now remained but the *cathartina* held in solution by acetic acid. By adding ammonia and evaporating to dryness it was obtained in a separate state.

Cathartina thus obtained has a yellowish-red colour, and cannot be made to assume a crystalline form. Its smell is peculiar, and its taste bitter and nauseous. It is very soluble both in water and alcohol ; but it is insoluble in ether. When exposed to the atmosphere it gradually absorbs moisture. Its aqueous solution is precipitated in brown flocks by the infusion of nutgalls. The diacetate of lead occasions a precipitate, having the same shade of colour. Sulphated peroxide of iron strikes with it a brown colour. The alkalies do not throw it down from its aqueous solution.

Whether it possesses alkaline properties has not been determined ; but it is probable that it does, because in senna it seems to be in the state of a malate, and because it combines with acetic acid. It possesses the purgative qualities of senna in great perfection.

SECTION IX.—OF GUARANINA.

This substance was discovered by Theod. Martius in the *guarana*, a Brazilian medicine obtained by drying the fruit of the *paullinia sorbilis*.*

To prepare it mix *guarana* in powder with one third of its weight of slacked lime, and digest the mixture in alcohol of the specific gravity 0·852, till every thing soluble be taken up. Filter the solution and distil off a little of the alcohol, then allow the liquid to cool in order to get rid of a greenish fat oil which will have made its appearance. After separating this oil continue the distillation till the greatest part of the alcohol is drawn off. The residue is to be evaporated to dryness, and the dry matter remaining heated in a subliming apparatus. The guaranina which first sublimes is yellow ; but afterwards it rises in the form of white feathery crystals.

Guaranina, thus obtained, is little soluble in water, but very soluble in alcohol. The solution has a bitter taste, and gives a green

* Kastner's Arch vii. 266.

colour to the tincture of rose leaves. When the alcoholic solution is evaporated the guaranina is deposited in the form of crystals.

It combines by fusion with phosphorus and sulphur, the compound is brown, and, when it is digested in water, the guaranina is dissolved. It combines also with iodine. When heated with concentrated sulphuric acid it is partly volatilized and partly decomposed. When assisted by heat it combines with the fixed oils and with camphor—the combination of it with camphor crystallizes; that with the fixed oils is partly crystalline, partly unctuous. The solution of guaranina is precipitated by the infusion of nutgalls.

Guaranina seems to possess alkaline properties; but hitherto none of its salts have been examined; nor have any experiments been made to determine its atomic weight or its ultimate constituents.

SECTION X.—OF HURINA.

There exists in the hot valleys which surround the table land of Bagota a tree named by the natives *Ajuapar*, which yields a yellow-coloured milk of a very acrid nature. When heated, it gives out fumes which attack the face and eyes, causing swelling, suppuration, and considerable pain. The ajuapar is said to be the *Hura crepitans* of botanists, a beautiful tree, the fruit of which is used in South America, instead of sand, for strewing upon fresh writing to prevent it from blotting. The milk of the ajuapar was examined, in 1825, by MM. Boussingault and Rivero.* They found it to contain a volatile oil to which its acridity may be ascribed, and an alkaline principle which we may distinguish by the name of *hurina*.

The milk was evaporated to the consistence of an extract, which was digested in alcohol of 0·837. The solution had a yellow colour, and reddened vegetable blues owing to the presence of a quantity of bimalate of potash. The alcoholic solution was evaporated, and the residual matter digested in water. A yellow viscid matter remained undissolved. This matter was well washed in boiling water. When digested in ether it was chiefly dissolved, but it left a small quantity of matter, which was the *hurina*.

Hurina, when thus left by the ether, has at first the appearance of an oil. But when the ether which it contains is completely driven off it assumes the form of small crystals, soluble in water and alcohol, and having an acrid and burning taste. The solutions of it redden turmeric paper, and restore the blue colour of litmus paper reddened by an acid.

These are only properties of this substance determined by Boussingault and Rivero. They are sufficient to show that it is an alkaloid; though none of its salts have been examined.

SECTION XI.—OF SANGUINARINA.

This substance was discovered by M. Dana in the root of the *sanguinaria canadensis*, which is occasionally used on the Continent as an emetic.†

* Ann. de Chim. et de Phys. xxviii. 430. † Mag. Pharm. xxiii. 125.

The root is digested in absolute alcohol till every thing soluble in that liquid is taken up. Water and ammonia being added to this solution a red precipitate falls. Wash this precipitate and boil it with water and ivory black. Decant off the watery portion and digest the ivory black and precipitate in alcohol. Filter and evaporate the alcoholic solution. The sanguinarina remains under the form of a white or pearl-grey matter. Its taste is bitter. It is insoluble in water, but dissolves in alcohol and ether; and possesses well-marked alkaline characters. It reddens turmeric paper, and with the acids forms red-coloured salts.

SECTION XII.—OF VIOLINA

It has been ascertained that several species of *viola* contain *emetina*. But Boullay is of opinion that the *viola oderata* contains a peculiar alkaline principle, analagous to emetina, to which he has given the name of *violina*.

To obtain this principle the alcoholic extract of the plant is treated with ether to dissolve some fatty matter and some chlorophylle. The residue is to be boiled with dilute sulphuric acid, and the solution is to be precipitated by hydrate of lead. The precipitate, consisting of sulphate of lead and *violina*, is to be dried and treated with alcohol. When this alcoholic solution is evaporated, the violina is left under the form of a pale yellow-coloured matter, which is to be washed with strong alcohol to deprive it of its colour.

According to Boullay, violina differs from emetina by giving a green colour to reddened litmus paper, while emetina renders it blue. It is more soluble in water and less soluble in alcohol than emetina. Ether and the oils do not dissolve it. Infusion of nutgalls throws it down. Like emetina it acts as an emetic.

SECTION XIII.—OF ESENBEKINA.

This alkaline principle has been detected by Buchner in the *Esenbekia febrifuga*.* The bark of this plant is boiled with acidulated water. The boiling hot solution is treated with magnesia, the precipitate is dried and digested in boiling alcohol till every thing soluble is taken up. When the alcoholic decoction is evaporated, the esenbekina remains in a mass, having a pigeon's-neck lustre.

It has a bitter taste like that of cinchona. It is slightly soluble in water, but is precipitated by oxalate of potash, infusion of nutgalls, or one of its own salts. When heated in a retort it gives out much ammonia.

SECTION XIV.—OF BUXINA.

Fauré informs us that he obtained from the *buxus sempervirens* an

* Unless this be the *Evolia febrifuga*, a tree which grows in Brazil, and which bears a close affinity to the *Cinchona*, I do not know what it is. The only species of *Esenbekia* which I have seen described is stated to be very closely allied to *evolia*, and is, like it, a native of Brazil.

alkaline principle, to which he has given the name of *buxina*.* His process was as follows:—

The bark of the *box tree* was digested in alcohol till every thing soluble was taken up. Evaporate the liquid and dissolve the residue in water, and boil the solution with ammonia. The precipitate, thus obtained, is digested in alcohol, which, being evaporated, leaves the buxina in the state of a dark-brown transluced mass.

It is difficult to render buxina white, even when treated with animal charcoal. It has a bitter taste and excites sneezing. It is insoluble in water, soluble in alcohol, and slightly so in ether. It restores the blue colour of reddened litmus paper, and forms neutral salts with the acids which have a more bitter taste than the buxina itself. The alkalies throw down from these salts white gelatinous precipitates. The sulphate of buxina crystallizes confusedly.

M. Couerbe has succeeded in obtaining buxina in crystals. His process was to add nitric acid to the sulphate of buxina. This acid removes a resinous matter and leaves sulphate of buxina pure. From the salt thus purified pure buxina may be precipitated in crystals.†

SECTION XV.—OF EUPATORINA.

This alkali is said to have been discovered by M. Righini in the flowers and leaves of the *Eupatorium cannabinum*, or *hemp agrimony*, a plant indigenous in Great Britain.‡

He boiled, for 2 hours, 2 lbs. of the leaves in 10 lbs. of water acidulated with half an ounce of sulphuric acid. This process was repeated. The two decoctions were mixed and saturated with lime. The precipitate obtained was exposed to the air to favour the action of sulphuric acid on the lime. It was then digested in 8 lbs. of alcohol of 0·817, during two days, in a temperature between 113° and 122°. The filtered liquor was then distilled to separate the alcohol. The residue evaporated in a porcelain basin yield the *eupatorina*. It is under the form of a white powder, having a peculiar taste analagous to that of the bitter principle contained in eupatoria; but at the same time sharp. It is insoluble in water, but soluble in ether and alcohol. When heated it swells up and burns. It combines with sulphuric acid, and forms a sulphate which crystallizes in silky needles.

Such are the characters given by Righini. But they are insufficient to distinguish it from other alkaloids. Nor have we any evidence that it was obtained in a state of purity.

SECTION XVI.—OF CRYSTALLINA.

When indigo is subjected to dry distillation, we obtain first water, and an oil, and afterwards resin, mixed with oil, comes over. The oil obtained by this process has been particularly examined by Unverdorben.§

It has a peculiar, but not disagreeable odour. Part oft his oil

* Jour. de Pharmacie, xvi. 428. † Ibid. xx. 51. ‡ Ibid. xiv. 623.
§ Poggendorf's Annalen, viii. 397.

constitutes an oily alkaline body, which Unverdorben distinguished by the name of *crystallina*, because it has the property of forming crystallizable salts with acids. It is extracted from the empyreumatic oil of indigo by means of sulphuric acid, which combines with it, and enables us to distil over the remaining ingredients of the empyreumatic oil. We have only to mix the sulphate of crystallina thus obtained with another base, and distil; the crystallina passes over into the receiver.

Thus obtained, crystallina is a colourless oil, which falls to the bottom of water. It has a peculiar and strong odour, somewhat resembling that of honey. It is very little soluble in water, but may be easily distilled over with that liquid. It does not restore the blue colour of litmus paper reddened by acids. When exposed to the air it becomes red. It is then soluble in water, communicating a yellow colour to that liquid.

Sulphate of crystallina, whether neutral, or containing an excess of acid, crystallizes. When the neutral salt is evaporated, it gives out crystallina, and passes to the state of a bisalt. It is insoluble in absolute alcohol. Its aqueous solution becomes gradually brown, and then contains sulphate of fuscin in solution. When the bisulphate is heated it melts, and, on cooling, concretes into a crystalline mass. When heated more strongly it is decomposed, sulphate of crystallina, sulphate of oderina, and a great deal of sulphate of ammonia being formed.

Phosphate of crystallina crystallizes easily when neutral, but the bisalt does not crystallize at all. Alcohol separates crystals by removing the excess of acid.

The other salts of this base have not been examined.*

SECTION XVII.—OF THEINA.

Oudry has lately announced that he has discovered in tea a salifiable basis, to which he has given the name of *theina*. To obtain it, let 12½ parts of tea be infused in 200 parts of water, holding in solution 3 parts of common salt. After 24 hours' infusion evaporate the liquid to dryness, and treat the dry residue with alcohol of the specific gravity 0·81. Evaporate the alcoholic solution, dissolve the residue in water, and digest the solution with magnesia. The liquor, filtered and evaporated to a certain degree of concentration, deposits crystals of theina. The magnesia, when digested in alcohol, gives up an additional quantity of *theina* to that liquid.

Theina at the temperature of 50°, requires from 35 to 40 times its weight of water to dissolve it. From that solution it may be obtained in fine prismatic needles. It dissolves in all proportions in alcohol, but that solution yields only ill-defined crystals. When theina is heated it melts, and at a still higher temperature undergoes decomposition, leaving a residue of charcoal. Oudry assures us that theina combines with sulphuric acid, and that the salt is capable of crystallizing.†

* See Poggendorf's Annalen, viii. 397.

† Nouvelle Bibl. Med., March 1827, and Mag. Pharm. xix. 49.

APPENDIX.

METHOD OF DETECTING THE VEGETABLE ALKALOIDS.

THE greater number of these alkaloids being poisonous, it comes to be an object of importance to be able to discover their presence, when they have been employed in order to destroy life. I shall, therefore, in this place, state the tests which have been discovered to obtain this object.

So far as we know at present, all the alkaloids are precipitated by tannin. The first step, therefore, when we examine a liquid, to discover whether it contains any of these bodies, is to drop into it a little of the fresh infusion of nutgalls. If an alkaloid be present, a bulky white precipitate will fall. Wash it with cold water. Then mix it intimately with a slight excess of slacked lime. Dry the mixture over the water-bath. Digest it in alcohol. Put the alcohol in a watch glass, and leave it to spontaneous evaporation. The alkaloid will crystallize.*

Morphina and strychnina crystallize in prisms; cinchonina in arborized needles; brucina in ramified plates; quinina does not crystallize at all, but its acetate crystallizes in beautiful feathers.†

I. ALKALOIDS IN OPIUM.

The alkaloids known to exist in opium are six in number, namely, thebaina, narcotina, codeina, morphina, meconin and narceina. These substances when in a solid and separate state, may be distinguished by agitating a few grains of each in half an ounce of sulphuric acid, containing some nitric acid mixed with it.‡

1. *Thebaina* instantly reddens, and the shade becomes gradually deeper. When viewed in a thin layer it has a yellowish aspect.

2. *Narcotina* becomes first yellow. It retains that colour for seven or eight minutes, and then becomes red. Even salts containing nitric acid produce this effect, according to the observation of M. Louis Mialhe de Vabre.§

3. *Codeina* assumes at first a weak green colour, which passes after some time to bluish-green.

4. *Morphina* instantly assumes a green colour.

5. *Meconin* is at first unaltered, but after 24 hours it assumes a fine rose-red colour.

6. *Narceina* assumes immediately a yellowish-red colour.

It was observed by Dr Meeson, in 1835,‖ that if a solution of morphina, or any of its salts, be mixed with a strong solution of chlorine, and ammonia be added, a dark-brown colour pervades the solution, which will disappear by the addition of more chlorine.

* O. Henry, Jour. de Pharmacie, xxi. 22. † Donné, Ibid. xvi. 374.
‡ Couerbe, Jour. de Pharmacie, xxii. 84. § Ibid. p. 585.
‖ Phil. Mag. (Third Series), vi. 158.

André, in 1836, found that when a little liquid chlorine is added to a weak aqueous solution of *morphina*, or any of its salts, the liquid becomes yellow, with a slight orange tint. Ammonia renders the colour more intense. An acid weakens, but does not destroy this colour.*

When solutions of narcotina are treated in the same way, no colour is produced.†

When iodic acid, or an acid iodate, is dropt into a solution of morphina, or a salt of morphina, the liquid immediately assumes a red colour.‡ The acid is decomposed by the morphina, and the iodine disengaged.

Perchloride of iron gives a deep-blue colour to morphina.

Morphina is precipitated from its solution in nitric acid by protochloride of tin of a *dirty-brown colour*.

When we wish to discover the presence of *morphina* in the contents of the stomach, or in sugared water, broth, milk, coffee, beer, &c., we must proceed in the following way:—

Let the liquid be acidulated by means of acetic acid, and let it be concentrated to the thickness of a syrup. Drop into it a little ammonia. A precipitate will fall, which must be collected on a filter, washed, and dried. It is pure morphina, which may be recognised by the characters given above. Should ammonia throw down no precipitate, which is apt to happen, especially when the morphina is dissolved in beer, we must, after having reduced the liquid to the consistence of a syrup, digest it in alcohol, and then precipitate the alcoholic solution by means of ammonia.§

M. Lassaigne has proposed a method nearly the same as the preceding, for detecting the presence of acetate of morphina in the contents of the stomach of animals poisoned by that substance. He filters the liquids contained in the stomach, evaporates them cautiously, and then digests the residue in boiling alcohol of 0·837, which separates the animal matter present. The alcohol is evaporated to the consistence of an extract, and treated by distilled water to separate any fatty matter that may be present. The liquid is then filtered, and evaporated slowly. Crystals of acetate of morphina gradually form, which may be detected by their characters.‖

The method of detecting morphina which has succeeded best with me, is to precipitate it by fresh made tincture of nutgalls. Alcohol dissolves the tannate of morphina. By the solution of isinglass the tannin may be separated from the morphina, and this latter substance obtained dissolved in alcohol. By evaporating the alcoholic solution, we obtain the morphina in a separate state, and can easily ascertain it by its characters.

II. STRYCHNINA, BRUCINA, VERATRINA.

Strychnina, when treated with sulphuric acid, assumes a yellow colour, passing into brown.¶

* André, Jour. de Pharmacie, xxii. 134. † André, Ibid.
‡ Serullas, Jour. de Pharm. xvi. 206. § Ibid. xviii. 52. ‖ Ibid. x. 206.
¶ Ibid. xviii. 46.

When the alcoholic solution of *brucina* is put in contact with bromine, it gives, after some time, a fine violet colour.

Veratrina, when treated with sulphuric acid, gives a beautiful violet colour.*

When chlorine is mixed with a solution of strychnina, that solution becomes milky. The addition of ammonia determines a precipitate, which gradually disappears, and the liquid remains milky.†

Brucina, when treated with chlorine, gives the same results as strychnina. But when treated with protochloride of tin, it gives a violet precipitate. Nitric acid tinges brucina yellow.

Iodic acid produces no sensible change upon solution of brucina and strychnina.

Strychnina, brucina, and veratrina, have the property of forming insoluble salts with muriatic acid. Advantage has been taken of this property to discover their presence in solutions. Evaporate the solutions containing them to the consistence of a syrup, then mix with the liquid a little muriatic acid and corrosive sublimate. A copious white precipitate falls, which being redissolved, and treated with sulphuret of barium and sulphuric acid, leaves a solution of the alkaloid present easily recognised by its properties.‡

When strychnina comes in contact with the vapour of iodine it becomes fine yellow, and brucina and veratrina become a dirty-yellow. The vapour of bromine changes veratrina and strychnina to yellow. It changes brucina to greenish-yellow.§

When strychnina is treated with sulphocyanate of potash, it becomes muddy, and deposits beautiful crystals in fine white stars. If we heat the liquid to 158° the crystals dissolve, but appear again in silky needles when the liquid cools to 63°½. In this way strychnina may be detected in a solution containing only $\frac{1}{373}$th of its weight of that alkaloid. When we mix corrosive sublimate with a solution of strychnina, and throw down the mercury by sulphuretted hydrogen, muriate of strychnina remains in solution, and may be recognised by its properties.‖

III. QUININA, CINCHONINA.

When a little liquid chlorine is added to a dilute aqueous solution of quinina, or salt of quinina (except the sulphate), the solution becomes slightly brown. This effect will not be sensible if the liquid contain an excess of acid. The chlorine first seizes upon the ammonia united to the resin of quinina, obliging it to remain in suspension for want of a solvent. The liquid becomess lightly blue; but on adding an excess of chlorine the resin is dissolved, and the colour disappears or becomes yellow. Ammonia throws down a green precipitate, which instantly redissolves, communicating a fine

* André, Jour. de Pharm. xxii. 135. † André, Ibid.
‡ Journal de Pharmacie, xviii. 53. § Ibid. xvi. 375.
‖ Artus Journ. für pract. Ch. iii. 320.

emerald-green colour.* If the solution of quinina thus treated be concentrated, the green is dull. If we very cautiously neutralize the ammonia, the liquid assumes a sky-blue colour. If too much acid be added the liquid becomes violet, or even red.†

When cinchonina is treated in the same way the liquid becomes red, with a shade of orange, and in 12 hours a brown precipitate falls.‡

Iodic acid does not affect solutions of quinina or cinchonina.§

The vapour of iodine gives a yellow colour both to quinina and cinchonina. The vapour of bromine also renders them yellow, inclining to orange.‖

IV. EMETINA.

This substance is distinguished from most of the others by its insolubility in ether, and its refusing to crystallize. Narcotina, for example, is very soluble in ether.

V. DELPHINA.

This alkaloid is precipitated by iodic acid, which is not the case with veratrina.

VI. SALICIN.

Salicin assumes a fine red colour when in contact with sulphuric acid. By this reagent we can detect salicin in a solution containing only $\frac{1}{6000}$th of its weight of it. We may even employ this reagent to detect the presence of salicin in a bark.

Boil a dram of the bark with four ounces of water. Filter and digest the liquid over a dram of oxide of lead in fine powder. Filter the discoloured liquid, precipitate any lead that it may contain, and evaporate till only one ounce of the liquid remains. Put a little of this liquid into a watch glass, and add, drop by drop, concentrated sulphuric acid. If salicin be present the liquid will assume a red colour.¶

* This interesting test was first made known to chemists by Dr Meeson, in 1835. See Phil. Mag. (Third Series), vi. 158.

† André, Ibid. xxii. 133. ‡ André, Ibid. p. 134.

§ Ibid. xviii. 46. ‖ Donné, ibid. xvi. 380. ¶ Duflos, Ibid. xix. 483.

CLASS III.

OF INTERMEDIATE BODIES.

Under this name I propose to include all the vegetable principles which seem capable of entering into definite compounds with other bodies, although it has not yet been proved by satisfactory experiments whether they are to be considered as acid or alkaline. This *class* is to be considered as merely temporary. I am obliged to admit it, in consequence of the imperfect investigation of many vegetable bodies, or rather groups of bodies. But our knowledge of these bodies is extending with very great rapidity; and I am satisfied that only a few years will elapse before this class of substances, at present so numerous and important, will find its place within the two preceding classes. I shall divide the intermediate bodies into 10 sets, which may be distinguished by the following names:—

I. Alcohol and its compounds.
II. Ethers.
III. Pyroxylic spirit.
IV. Acetone.
V. Mesite.
VI. Colouring matters.
VII. Fixed oils.
VIII. Volatile oils.
IX. Resins.
X. Gum resins.

These different important groups of bodies will occupy our attention, in succession, in the following Chapters.

CHAPTER I.

OF ALCOHOL AND ITS COMPOUNDS.

In the 2d volume of the *Chemistry of Inorganic Bodies* (p. 263), a pretty full account has been given of alcohol and its compounds. But since 1831, when that volume was published, many valuable additions have been made to our knowledge. Of these I propose to give an account here.

1. *Common alcohol.* It has been long known that alcohol in the state of vapour is a compound of

	Sp. Gravity.
1 volume olefiant gas . .	0·9722
1 volume vapour of water . .	0·6250
	1·5972

condensed into 1 volume: so that its specific gravity is 1·5972, when in the state of vapour.

Olefiant gas is a compound, 2 volumes carbon vapour, and 2 volumes hydrogen gas united together, and condensed into 1 volume. So that a volume of it is equivalent to 2 atoms carbon, and 2 atoms hydrogen.

Liebig has given another view of the composition of alcohol, founded upon the experiments lately made to determine the composition of ether. According to him, ether contains no water. But is composed of $C^4 H^5 + O$, or it is an oxide of $(C^4 H^5)$. Alcohol is a hydrate of ether, or it consists of $(C^4 H^5 O) + H O$. This view recommends itself by its simplicity, and by the facility which it presents to us in explaining the nature of the numerous compounds formed by means of alcohol.

I propose here to give an account of the compound bodies from alcohol that have been discovered since the year 1831.

SECTION I.—OF ALDEHYDE.*

This remarkable substance was first noticed by Dobereiner, but for every thing determined or known respecting it, we are indebted to Professor Liebig.†

It may be obtained either from alcohol or ether. If we pass the vapour of ether deprived of water and alcohol through a large glass tube filled with fragments of glass, and heated to redness, it is entirely changed into aldehyde, inflammable gas, and water. There is at the same time a very small quantity of charcoal deposited. If we cause these products to pass into a vessel half filled with ether, and carefully cooled, the aldehyde is retained in solution. If from time to time, and without interrupting the process, we saturate the ether receiving the gaseous substances with dry ammoniacal gas, the sides and bottom of the vessel are gradually covered with bright transparent crystals, which are composed of aldehyde and ammonia. We obtain them pure by pressing them between folds of blotting paper, and then drying them in the open air to deprive them of a little adhering water.

If we mix together 4 parts of alcohol of the specific gravity 0·818, 6 parts of binoxide of manganese, 6 parts of sulphuric acid, and 4 parts of water, and distil by a gentle heat, the liquid (which froths a little) gives out aldehyde mixed with alcohol and some other products. The aldehyde is so exceedingly volatile, that unless the receiver be kept very cool, a considerable loss is sustained. When about 6 parts have been distilled off, the product begins to become acid and then we must stop the process.

The liquid thus obtained is put into a retort, together with its own weight of chloride of calcium, from which one half of the liquid

* This word is formed from *alcohol dehydratus*. The first syllables of the two words being united together.

† Ann. de Chim. et de Phys. lix. 296, and Ann. der Pharmacie, xiv. 133.

is distilled off by the water-bath. This portion is put into a retort a second time with its own weight of chloride of calcium, and the distillation again repeated. By these repeated distillations, the aldehyde is deprived of all its water, and of a considerable part of the alcohol and other bodies with which it was mixed.

The liquid thus obtained is to be mixed with twice its volume of ether and dry ammoniacal gas passed into it. Much heat is evolved during this process, and on that account we must surround the vessel containing the mixture with cold water. An intermediate vessel furnished with a tube of safety, ought to be interposed between the vessel in which the ammoniacal gas is disengaged, and that containing the mixture; for the absorption of the gas is so rapid that without this precaution the liquid would certainly pass into the ammoniacal vessel, and the process would be spoiled. Abundance of transparent colourless crystals precipitate as the process goes on. These crystals are composed of aldehyde united to ammonia. They must be washed twice or thrice with a little ether to render them pure. To these crystals Liebig has given the name of *ammonialdehyde*.

To obtain aldehyde from these crystals, dissolve two parts of them in their own weight of water, put the solution into a retort, and add three parts of sulphuric acid, previously diluted with four parts of water. When the mixture is gently heated on the water-bath, the aldehyde is disengaged with a strong effervescence. The water in the bath must not be raised to the boiling point. What comes over is hydrated aldehyde. It is put into a retort with its own bulk of chloride of calcium, and distilled over the water-bath, taking care to cool the retort when the two substances are brought into contact, because so much heat is otherwise evolved, as would dissipate most of the aldehyde. By repeating this distillation twice, the aldehyde is obtained perfectly pure.

It is a colourless liquid, limpid like water, very volatile, having a specific gravity of 0·790 and boiling when heated to the temperature of 71°¼. It has a peculiar etherial and penetrating odour. When we draw this vapour into the lungs, we lose for an instant the power of breathing air. It produces a kind of cramp in the stomach.

With water it combines in all proportions, heat being at the same time evolved. When chloride of calcium is added to the mixture, the aldehyde separates under the form of a limpid stratum which swims on the surface. With alcohol and ether it behaves as with water. The ether cannot be again separated from it by agitation in water. Its volatility is much diminished when it is combined with water or alcohol. These solutions have no action whatever on vegetable colours.

Aldehyde takes fire readily, and burns with a pale flame, which emits a good deal of light. When kept in a vessel full of air, it absorbs oxygen, and is gradually converted into very concentrated acetic acid. When spongy platinum is introduced, the action goes on with uncommon rapidity. If we let fall a drop of it into a vessel

full of moist air, we immediately perceive a strong smell of acetic acid.

Aldehyde dissolves sulphur, phosphorus, and iodine; but these bodies do not appear to undergo any alteration. Chlorine and bromine are absorbed with the evolution of much heat, while muriatic and hydrobromic acids are produced. Liebig is of opinion that in these reactions the aldehyde is changed into *chloral* and *bromal*. Weak nitric acid, when heated with aldehyde, decomposes it, nitrous acid being disengaged, and acetic acid formed. Concentrated sulphuric acid when mixed with it becomes immediately deep-brown, and afterwards black and thick.

When hydrated aldehyde is heated with potash, the liquid becomes first yellowish and muddy. In a short time a brownish-red resinous matter separates and swims on the surface. To this matter Liebig has given the name of *aldehyde resin*.

If we heat aldehyde with water and oxide of silver at first moderately, and then raise the liquid to the boiling temperature in a glass tube, the silver is revived, and covers the glass with a brilliant coating, like a mirror; showing that no gas is evolved during this process. After this reduction we have in the liquid a salt of silver, and the liquid may be evaporated without any farther reduction of the silver to the metallic state. If we add to this liquid, after allowing it to cool, as much barytes water as is requisite to throw down all the oxide of silver, and if we now heat the liquid without removing the precipitated oxide, the whole silver is reduced to the metallic state without the evolution of any gas. If we mix the liquid with nitrate of silver, immediately a great number of plates of acetate of silver are deposited, and no other product is observed but acetic acid. Thus it appears, that when the salt of barytes is boiled with oxide of silver, the acid in combination with the barytes, is converted into acetic acid by the absorption of oxygen.

The very same phenomena are observed when aqueous aldehyde, to which a few drops of ammonia have been added, is heated with oxide of silver. The reduction of oxide of silver which takes place in this experiment affords an easy method of ascertaining the presence of the smallest quantity of aldehyde in any liquid in which it may be suspected.

When aldehyde is kept in vessels to which air has access, oxygen is absorbed, and a number of prismatic crystals are formed. These crystals fuse when heated to 212°, and when raised to a higher temperature, sublime in splendent transparent white needles. They are hard, easily pulverised, inflammable, without smell, soluble in alcohol and ether, but not in water. Besides these crystals, there is a liquid which makes its appearance in the aldehyde, very similar to acetal in its characters.

Liebig analyzed aldehyde in the usual way, by heating it with oxide of copper. Its great volatility renders the process difficult. The result was as follows:—

Carbon	53·67 or 4 atoms	= 3·0	or per cent.	54·55
Hydrogen	8·97 or 4 atoms	= 0·5	— —	9·09
Oxygen	37·36 or 2 atoms	= 2	— —	36·36
	100·00	5·5		100·00

M. Liebig determined the density of the vapour of aldehyde, and found it 1·532.

Now, if we consider vapour of aldehyde as composed of 4 volumes carbon vapour, 4 volumes hydrogen gas, and 1 volume oxygen gas, condensed into 2 volumes, we have

4 volumes carbon vapour .	= 1·6666
4 volumes hydrogen gas .	= 0·2777
1 volume oxygen gas .	= 1·1111
	2) 2·9555
	1·4777 = sp. gravity

of aldehyde vapour. The vapour then is composed of 4 volumes carbon, 4 volumes hydrogen, and 1 volume oxygen, condensed into 2 volumes.

Now that the composition of aldehyde is known, it is easy to see how, by means of oxygen, it is converted with such facility into acetic acid.

Acetic acid . . .	$C^4 H^3 O^3$
Aldehyde	$C^4 H^4 O^2$

If therefore the oxygen combine with one of the atoms of hydrogen, and convert it into water, while another atom of oxygen replaces the hydrogen, it is obvious that aldehyde will become acetic acid.

Liebig is of opinion that there exists an unknown basis composed of $C^4 H^3$, to which he has given the name of *aldehyden*. The oxide of this basis is $C^4 H^3 O$, and when this oxide is combined with an atom of water it constitutes aldehyde, the true formula for which is $C^4 H^3 O + HO$. Acetic acid is $C^4 H^3 O^3 + HO$.

It is obvious also that alcohol and aldehyde differ from each other merely by the aldehyde containing 2 atoms less hydrogen than alcohol.

Alcohol is . . .	$C^4 H^6 O^2$
Aldehyde . . .	$C^4 H^4 O^2$

Ammonialdehyde. The preparation of this salt has been already described. The crystals are acute rhomboids, the faces of which meet at an angle of about 85°. They are colourless, transparent, and refract the light strongly. They have the hardness of loaf sugar and are easily reduced to powder. They have a smell both of ammonia and turpentine. They are volatile, melt when heated to between 158° and 176°; probably about 167°, and they may be distilled unaltered at the temperature of 212°. Their vapour reddens turmeric paper, and their aqueous solution acts as an alkali. The acids, even the acetic, decompose this salt. An ammoniacal salt is formed, and aldehyde is set at liberty. It is exceedingly soluble in water, a little less so in alcohol, and with difficulty in ether.

When exposed to the air and light the crystals become yellow, and acquire an odour resembling burning animal substances. If these crystals, after they have become brown, be distilled over the water-bath, ammonialdehyde sublimes in its usual state of purity, and there remains a brown resin, insoluble in water, which contains acetate of ammonia, and another ammoniacal salt.

We obtain crystals of ammonialdehyde of uncommon size and beauty if we mix ether with a concentrated alcoholic solution of the salt, and allow the mixture to remain in a state of rest.

This compound behaves to acids and alkalies as aldehyde does. When we heat it with water and oxide of silver, aldehyde and ammonia are disengaged; a portion of the oxide of silver is reduced, and the other phenomena take place which have been already described.

This salt was subjected to analysis by Liebig, by means of oxide of copper. He obtained the following results:—

Carbon	39·8 or 4 atoms	= 3	or per cent. 39·34
Hydrogen	11·4 or 7 atoms	= 0·875	— — 11·47
Azote	23·0 or 1 atom	= 1·75	— — 22·96
Oxygen	25·8 or 2 atoms	= 2·00	— — 26·23
	100·0	7·625	100·00

These atomic numbers may be resolved into

1 atom aldehyde .	$C^4 H^4 O^2$
1 atom ammonia .	H^3 Az
	$C^4 H^7 O^2$ Az

If we mix together concentrated solutions of ammonia, aldehyde, and nitrate of silver, a white, brilliant, granular precipitate falls, readily soluble in water, but with difficulty in alcohol. It may, therefore, be obtained pure by washing it with spirit of wine. If the solution of this precipitate be gently heated, aldehyde is disengaged, and a portion of the oxide of silver reduced. If we heat the solution with concentrated sulphuric acid, nitrous acid is disengaged, and if we mix it with lime there is a disengagement of ammonia. Hence it appears that the precipitate contains aldehyde, ammonia, nitric acid, and oxide of silver. Liebig's attempt to analyze it did not succeed. But it is obviously a combination of ammonialdehyde and nitrate of silver, in proportions not yet determined.

Aldehyde resin. It has been already observed, that when an aqueous solution of aldehyde is heated in contact with a solution of potash, the liquid becomes muddy and yellowish, and speedily a soft brownish-red matter comes to the surface, having a spirituous, but disagreeable smell, and so adhesive that it may be drawn out into threads. This matter is produced when potash is dissolved in alcohol, and most speedily when the access of air is permitted. It is to the presence of this substance that the alcoholic solution of potash owes its reddish-brown colour. It is produced also in a few minutes when a solution of potash in alcohol and acetal is exposed

to the air. This is a useful character to enable us to distinguish acetal from acetic ether and other etherial liquids. All the liquids containing aldehyde, nitric ether, muriatic ether, &c., assume a reddish-brown colour when heated with potash; and when diluted with water, or an acid, the resin of aldehyde separates in brown flocks.

If the liquid obtained by distilling a mixture of spirit of wine, binoxide of manganese, and sulphuric acid, be heated to the boiling temperature, and then mixed with water, an abundant precipitate of resin of aldehyde is obtained. When this substance is boiled in water it collects into lumps, becomes of a deep-brown, almost black colour, and when pounded gives a light-brown powder. This powder, when washed in water, forms a deep brown-coloured solution.

If we dry this substance first at the ordinary temperature of the atmosphere, and then at the temperature of boiling water, we observe a peculiar spirituous smell, and it sometimes takes fire of its own accord at that temperature, and burns like tinder. When heated in a spoon it burns like resin, leaving a brilliant charcoal, difficult to incinerate. It was analyzed by Liebig, and its constituents were found:

Carbon	73·3405 or 5 atoms	= 3·75	or per cent. 73·17
Hydrogen	7·7590 or 3 atoms	= 0·375	— — 7·31
Oxygen	18·9005 or 1 atom	= 1·00	— — 19·52
	100·0000	5·125	100·00

But the analysis is scarcely entitled to confidence.

Aldehydic acid. It has been shown that when aldehyde is made to act upon oxide of silver, a portion of the silver is reduced, and that an acid is formed which combines with another portion of the oxide of silver, and forms a salt, decomposable by barytes, and that then the acid is easily converted into acetic acid. Liebig has given to this acid the name of *aldehydic acid.**

The action of this acid on the oxides of mercury and silver, and on the salts of these oxides, enables us to distinguish it from all other acids.

When mixed with nitrate of silver, the liquid becomes muddy; when heated it assumes a blue colour, and the glass becomes covered with metallic silver. The same phenomena appear when the acid is mixed with solutions of gold or platinum.

Oxide of silver dissolves in this acid; but when the solution is heated the silver is reduced. Nitrate of mercury, heated with this acid, is immediately decomposed. A kind of metallic shower falls, and brilliant globules of mercury collect at the bottom of the vessel. The red oxide of mercury dissolves in the acid. When heated a

* He considers it as the *lampic acid* of Daniell. But Mr Connel has shown that lampic acid is a mixture of about 5 parts of formic acid, and 1 part of acetic acid.—See Phil. Mag. (Third Series), xi. 512.

white salt in micacious crystals is formed, and metallic mercury separates at the same time.

When this acid is neutralized by barytes, a salt is formed, which is not easily crystallized, and which deliquesces in moist air. It acts upon the salts of mercury and silver in the same way as the free acid.

When the salt formed by the combination of this acid with oxide of copper is heated, the copper is reduced. Aldehydic acid is decomposed by sulphuric acid with the deposition of charcoal.

Liebig has ascertained that when oxide of silver is heated with aldehyde, one half of the oxide is reduced to the metallic state, while the aldehyde becomes aldehydic acid. Hence it is obvious that an atom of aldehyde, to be converted into aldehydic acid, requires to combine with one atom of oxygen. Hence aldehydic acid is composed of

$$C^4\ H^4\ O^3$$

It differs from acetic acid merely by containing an additional atom of hydrogen. Hence the facility with which it is converted into acetic acid by the action of oxide of silver.

SECTION II.—OF COMPOUNDS OF ALDEHYDEN.

It has been already stated that Liebig conceives that there exists an unknown base composed of $C^4\ H^3$, of which aldehyde constitutes a hydrated oxide. M. Regnault has rendered this opinion exceedingly probable, by discovering compounds of this unknown base with chlorine, bromine, and iodine. The two last of these we shall here describe.

1. *Bromide of aldehyden.* If we mix together an alcoholic solution of bromide of deutocarbohydrogen (*olefiant gas*), with a concentrated alcoholic solution of potash, a white precipitate falls, and the liquid begins to boil, giving out a peculiar smell. If we keep the mixture in a temperature between 86° and 100° an ethereal gas, with the smell of garlic, is disengaged. To this substance Regnault has given the name of *bromide of aldehyden.* To render it pure it may be passed through a little water, and then through a long tube filled with chloride of calcium. When exposed to a freezing mixture of snow and salt, it is converted into a thick liquid. In this state it was mixed with oxide of copper, and analyzed by Regnault, who obtained

Carbon	22·17 or 4 atoms	=	3	or per cent.	22·43
Hydrogen	2·92 or 3 atoms	=	0·375	— —	2·80
Bromine	74·91 or 1 atom	=	10	— —	74·77
	100·00*		13·375		100

Regnault determined the specific gravity of this bromide in the state of vapour, and found it 3·691. Now

* Ann. der Pharm. xv. 64.

4 volumes carbon vapour	weigh	1·6666
3 — hydrogen	—	0·2083
1 volume bromine	—	5·5400
		2)7·4150
		3·7075

It is therefore composed of 4 volumes of carbon vapour, 3 volumes of hydrogen gas, and 1 volume of bromine vapour, united together, and condensed into 2 volumes, or to a fourth part of the original bulk, before combination.

Bromide of aldehyden, in a liquid state, is a colourless and very volatile fluid. Its specific gravity is 1·52. Its smell resembles that of garlic, but is not disagreeable. It boils at the common temperature of the atmosphere, and when in the state of gas is absorbed in considerable quantity by water. Chlorine decomposes it, and converts it into the chloride of olefiant gas. Bromine decomposes it also. A portion of liquid bromide of aldehyden was mixed with bromine, and exposed in a close glass balloon to the solar light for several days. On opening the vessel a quantity of acid vapour, probably *hydrobromic acid*, escaped. When the liquid remaining was washed with alkaline water, an etherial liquid fell to the bottom, which was heavier than sulphuric acid. It boiled at a temperature above 212°, and had a perfect resemblance to bromide of bicarbohydrogen. Regnault considers it as identical with this bromide, though he did not succeed in making a satisfactory analysis of it.

Neither hydrobromic nor muriatic acid decompose bromide of aldehyden. Potassium slowly decomposes it, being converted into bromide of potassium. The decomposition goes on much more rapidly when heat is applied. The potassium becomes red-hot, and charcoal is disengaged. But no $C^4 H^3$ is evolved.

When bromide of aldehyden is passed through a hot tube containing metallic iron, charcoal is always deposited, and a gas is disengaged, which seems to be a carbohydrogen. When the tube was of an incipient red heat, the gas evolved was a compound of 110 volumes hydrogen, and 45 carbon, and a strong smell of naphthaline was perceptible.

2. *Iodide of aldehyden.** When a concentrated solution of caustic alkali is poured upon iodide of bicarbohydrogen, a lively action is produced, and a gas is evolved, having the smell of garlic, similar to that given out by chloride and bromide of bicarbohydrogen under like circumstances. After some time the decomposition ceases, and can only be completed when the mixture is heated to between 122° and 140°. This gas may be purified by passing it through a little water, and then through a long tube filled with chloride of calcium. When exposed to a freezing mixture of snow and salt, it is converted

* Regnault, Ann. der Pharm. xv. 69.

into a liquid, which afterwards continues in that state, even at the usual temperature of the atmosphere. A portion, however, retains the gaseous state, and still smells feebly of garlic. This gas, from the analysis of Regnault, appeared to be bicarbohydrogen.

The liquid portion was the iodide of aldehyden, had a specific gravity, when in a state of vapour, of 4·76. Now,

4 volumes carbon	weigh .	1·6666
3 — hydrogen	— .	0·2083
1 volume iodine	— .	8·8
		2)10·6750
		5·3375

We see from this that, like bromide of aldehyden, it is composed of 4 volumes carbon, 3 volumes hydrogen, and 1 volume of iodine vapours, condensed into 2 volumes.

SECTION III.—OF ACETAL.

This substance was discovered by Dobereiner, but examined and named by M. Liebig, in 1833.* Dobereiner's process was the following:—

Alcohol of the specific gravity 0·8631 was put upon a saucer; a support was placed in the saucer, the top of which is raised a few lines above the alcohol; and upon this support a number of watch glasses are arranged, having a quantity of spongy platinum in each. The whole is covered by a bell glass, open above, so that the walls of the glass are in the saucer containing the alcohol, in order that the vapours which condense upon them may tumble back into the alcohol. The apparatus thus disposed is left in a place not too cool till the alcohol acquires a very acid taste. The whole is then distilled over carbonate of lime. To the product of this distillation chloride of calcium in powder is added. This causes the separation of an etherial liquor, to which Liebig has given the name of *acetal*.

It is colourless, as fluid as ether, and has a smell, which Dobereiner refers to that of nitric ether—Liebig to that of muriatic ether. Its specific gravity is 0·823. It boils at 203°. It may be mixed with alcohol and ether in any proportion. Water dissolves the sixth part of its weight of it. It burns with a bright flame. When the action of spongy platinum is prolonged, the acetal is converted into acetic acid. The addition of potash changes it into a brown resin, and sulphuric acid produces this change still more rapidly. But Liebig has shown that this resinous matter is not formed when the acetal is pure.

It was analyzed by Liebig, who obtained

* Ann. der Pharmacie, v. 25.

Carbon	58·72 or 8 atoms	= 6	or per cent.	59·26
Hydrogen	11·35 or 9 atoms	= 1·125	— —	11·11
Oxygen	29·93 or 3 atoms	= 3	— —	29·63
	100·00	10·125		100·00

If we compare this formula with that which gives the constitution of alcohol, it will be obvious that the action of the spongy platinum consists in the combination of the oxygen of the atmosphere with part of the hydrogen of the alcohol—

2 atoms alcohol.	$O^8 H^{12} O^4$
Take away 2 atoms hydrogen, 1 atom water	$H^3 O$
Remain	$C^8 H^9 O$ or acetal.

We might also consider acetal as a compound of 1 atom acetic acid . . . . . $C^4 H^3 O^3$

3 atoms ether . . $C^{12} H^{15} O^3$

$C^{16} H^{18} O^6$

For it is obvious that $C^{16} H^{18} O^6$ is a multiple of $C^8 H^9 O^3$.

Or, what is still simpler, we may consider it as $C^4 H^4 + H^3 O^{1\frac{1}{2}}$, and then it would come under the second set of compounds mentioned in the next Chapter, as incorrectly called ethers.

SECTION IV.—OF DEUTOCARBOHYDROGEN.

Olefiant gas, which I distinguish by this name, has been described at sufficient length in the *Chemistry of Inorganic Bodies*. But several compounds of it, which have been lately formed, or more accurately examined, require to be noticed here:—

1. *Chloride of deutocarbohydrogen*, or *oil of the Dutch chemists*. This substance, rendered as pure as possible, was analyzed by Regnault, who obtained

Carbon	24·02 or 2 atoms	= 1·5	or per cent.	24
Hydrogen	4·04 or 2 atoms	= 0·25	— —	4
Chlorine	72·38 or 1 atom	= 4·5	— —	72
	100·44*	6·25		100

This analysis corresponds with that of Dumas.

The specific gravity of the oily liquid was 1·256. Regnault found the boiling point 180°·5.

The specific gravity of its vapour was 3·45. Now,

2 volumes carbon weigh .	0·8333
2 — hydrogen — .	0·1388
1 volume chlorine gas — .	2·5000
	3·4722

Hence it is obviously composed of 2 volumes carbon, 2 volumes hydrogen, and 1 volume chlorine gas, condensed into 1 volume.

* Ann. der Pharmacie, xiv. 22.

It is obvious from this that only one half of the olefiant gas combines with the chlorine. When the oil is mixed with hydrate of potash, chloride of potassium is formed, and a gas escapes, which seems, from Regnault's trials, to consist of C^2 $H^{1\frac{1}{2}}$. Doubtless the oxygen of the potash converts the rest of the hydrogen into water. But it contains also chlorine.

M. Laurent found, that by continuing to pass a current of chlorine through chloride of deutocarbohydrogen, it continued to be absorbed, and muriatic acid disengaged. He stopped the process on the third day, and obtained, by distilling the product, a colourless liquid, heavier than water, and having a peculiar aromatic smell. It burned with a green fuliginous flame, was insoluble in water, but very soluble in alcohol and ether. When it was heated with caustic potash, a lively effervescence took place, and an oil was distilled over, having an excessively pungent smell. Laurent has given this liquid the name of *muriate of chloretherise.* He analyzed this liquid, and obtained

Carbon	14·29 or 8 atoms =	6	or per cent.	14·12
Hydrogen	1·29 or 4 atoms =	0·5	— —	1·17
Chlorine	84·42 or 8 atoms =	36	— —	84·71
	100·00	42·5		100

So that one half of the hydrogen has been replaced by chlorine.* When we continue, the chlorine crystals are formed, which Laurent considers as chloride of carbon.

2. *Bromide of deutocarbohydrogen.* Regnault formed this compound by letting bromine fall, drop by drop, on a stream of olefiant gas. The colour of the bromine disappeared, and an ethereal liquid was formed, which was bromide of deutocarbohydrogen.

It is a colourless, very fluid liquid, having a sweet taste, an ethereal smell, and resembling chloride of olefiant gas. It stains paper, but the stains speedily disappear. Its specific gravity is 2·164. It boils at 264°, and when cooled down to 5° it concretes into a white crystalline mass, like camphor. It was analyzed by Regnault, and found composed of

Carbon	12·63 or 2 atoms =	1·50	or per cent.	12·78
Hydrogen	2·21 or 2 atoms =	0·25	— —	2·12
Bromine	85·16 or 1 atom =	10·00	— —	85·10
	100·00†	11·75		100

So that it is exactly analogous to chloride of deutocarbohydrogen.

The specific gravity of the vapour of this compound is 6·485. Now, the weight of

2 volumes carbon is . .	0·8333
2 — hydrogen . .	0·1388
1 volume bromine . .	5·4400
	6·4122

* Ann. de Chim. et de Phys. lxiii. 377. † Ann. der Pharm. xv. 60.

3. *Iodide of deutocarbohydrogen.* When olefiant gas is passed into a glass balloon with a long neck, in the bottom of which iodine lies, and which is heated to between 122° and 140°, the iodine soon fuses, assumes a brown colour, and yellow needle-shaped crystals are deposited in the neck of the glass. These, if the current of olefiant gas be continued, become quite white. They must be treated with a solution of potash or ammonia, then washed in pure water, and finally dried *in vacuo* over sulphuric acid. When dry it is yellowish, but may be obtained white when triturated with mercury, and then exposed to a stream of dry air, at a temperature between 113° and 122°.

Iodide of deutocarbohydrogen thus prepared has a silky lustre, and a smell which excites headach, and occasions a flow of tears. It undergoes spontaneous decomposition, even if kept in the dark. It melts at 163°½. In a somewhat higher temperature (but on the water-bath) it becomes brown, and is completely decomposed. It is insoluble in water, but soluble in alcohol, though in smaller quantity than the chloride and bromide of deutocarbohydrogen.

It was analyzed by M. Regnault, who obtained

Carbon	8·46 or 2 atoms =	1·5	or per cent.	8·57
Hydrogen	1·46 or 2 atoms =	0·25	— —	1·43
Iodine	90·08 or 1 atom =	15·75	— —	90·00
	100·00*	17·5		100·00

This iodide is so easily decomposed, that we cannot determine the specific gravity of its vapour. It ought, from analogy, to be 9·7722.

When a stream of chlorine gas is passed over it, decomposition takes place, chloride of iodine is formed, and chloride of deutocarbohydrogen. Bromine decomposes it in the same manner. Potassium decomposes it without the assistance of heat. It is decomposed also by the alcoholic solution of potash

There is obviously a close relation between aldehyden and olefiant gas.

Aldehyden is . . .	$C^4 H^3$
Chloride of aldehyden . .	$C^4 H^3 + Chl$
Bromide of aldehyden . .	$C^4 H^3 + Br$
Iodide of aldehyden . .	$C^4 H^3 + Iod$
Olefiant gas . . .	$C^4 H^3 + H$
Chloride of deutocarbohydrogen	$C^4 H^3 Chl + H Chl$
Bromide of deutocarbohydrogen	$C^4 H^3 Br + H Br$
Iodide of deutocarbohydrogen	$C^4 H^3 Iod + H Iod$
Aldehyde	$C^4 H^3 O + H O$
Aldehydic acid . . .	$C^4 H^3 O^2 + H O$
Acetic acid	$C^4 H^3 O^3 + H O$

SECTION V.—OF CHLOROFORM.

This remarkable substance was discovered about the same time

* Ann. der Pharm. xv. 68.

by MM. Soubeiran* and Liebig.† Somewhat later, its properties were investigated by M. Dumas.‡

It is easily obtained by distilling a mixture of alcohol and aqueous solution of *chlorite of lime*, or bleaching powder.

It is a limpid and transparent colourless liquid. Its smell and several of its other characters have some analogy with those of *hydrocarburet of chlorine*.

Its specific gravity is 1·480. It boils when heated to the temperature of 141°½. The specific gravity of its vapour is 4·199.

It is not inflammable. But if a glass rod moistened with it be put into the flame of burning alcohol we observe a yellow fuliginous flame. Hydrocarburet of chlorine, in the same circumstances, burns with a large luminous flame, the lower edge of which is coloured green.

If vapour of chloroform be passed over red-hot iron or copper it is entirely decomposed. We obtain a metallic chloride covered with charcoal; but no inflammable gas, if the experiments of Liebig be accurate. If its vapours be passed through a glass tube raised to a dull red heat we obtain a small quantity of gas, a portion of which is absorbed by water, and another is combustible and burns with a green-coloured flame. The inner surface of the tube becomes black and is covered with a number of white filamentous crystals, which, (judging from their smell) have a great resemblance to Faraday's solid chloride of carbon.

It is decomposed by lime at a dull-red heat, and no trace of inflammable gas disengaged can be observed. At a higher temperature carbonic oxide gas is obtained, occasioned by the action of the charcoal deposited on the carbonate of lime produced.

Chloroform is not decomposed by potassium. It may be distilled off that metal without occasioning the smallest alteration. At the commencement of the process, indeed, some bubbles of hydrogen gas may be observed, which increase when the liquid is raised to the boiling temperature. When potassium is heated in the vapour of chloroform it burns with an explosion, chloride of potassium being formed and charcoal deposited.

When long boiled with the alkaline hydrates chloroform is converted into chloride and formate of the alkali used.

Alcohol and ether dissolve it readily; but water throws it down from these solutions. It dissolves sulphur, phosphorus and iodine, without undergoing any alteration in its characters.

When chloral is mixed with milk of lime, potash, or barytes water, and distilled, chloroform is obtained. A very dense, limpid, and transparent liquor comes over. It must be repeatedly agitated with pure water, and, after having drawn off the greatest part of the water with a sucker, a quantity of sulphuric acid, about six or eight times the volume of the residual liquid, is added. The whole is violently shaken, and the chloroform which swims on the surface, is drawn off.

* Ann. de Chim. et de Phys. xlviii. 151. † Ibid. xlix. 146. ‡ Ibid. lvi. 113.

It is finally distilled off barytes in a dry apparatus. In this way chloroform free from water may be obtained.

But the easiest method of obtaining it is by means of bleaching powder, as mentioned at the beginning of this Section. Mix together 1 pound of chlorite of lime, 3 lbs. of water, and 2 or 3 ounces of spirit of wine, and distil. As the liquid froths much during the distillation, the process must be conducted in a large retort.

Acetone distilled in the same way with chlorite of lime yields chloroform in still greater abundance.

Chloroform has been subjected to analysis by Subeiran, Liebig, and Dumas. I consider the result obtained by this last chemist as nearest the truth. He had the advantage of the labours of the two former experimenters to guide his processes.

The mean of three analyses agreeing very well with each other, give the constituents of chloroform as follows:—

Carbon	10·11 or 2 atoms	=	1·5	or per cent.	9·92
Hydrogen	0·91 or 1 atom	=	0·125	— —	0·83
Chlorine	88·98 or 3 atoms	=	13·5	— —	89·25
	100·00		15·125		100·00

If we consider its vapour as composed of

2 volumes carbon . .	= 0·8333
1 volume hydrogen gas .	= 0·0694
3 volumes chlorine gas .	= 7·5
	2)8·3997
	4·1998

condensed into 2 volumes, its specific gravity would be 4·1998. Now we have stated above that Dumas found its specific gravity to be 4·199. Thus there can be no doubt whatever about the constitution of chloroform. It is a compound of 1 atom bicarburet of hydrogen with 3 atoms chlorine.

SECTION VI.—OF BROMOFORM.

This compound, analagous to the last, was discovered by M. Dumas, in 1834.* It is obtained when a mixture of bromide of lime and alcohol, or acetone, is distilled, precisely as to prepare chloroform. The phenomena are the same, and we obtain a heavy oily-looking liquid. When agitated with sulphuric acid, and then left at rest, it falls to the bottom of the vessel, because it is heavier than concentrated sulphuric acid. It must be drawn off by a sucker, and rectified by distillation. When placed in contact with fused chloride of calcium it abandons the alcohol or water which it may have retained. The chloride of calcium swims, being lighter than bromoform. On this account frequent agitation is necessary to enable the salt to remove all the water or alcohol.

* Ann. de Chim. et de Phys. lvi. 120.

Being less volatile than chloroform, it is more easily converted into bromide of potassium and formate of potash when boiled with a solution of that alkali.

The other properties of this substance have not hitherto been ascertained. But Dumas subjected it to a chemical analysis, and obtained

Carbon	5·32 or 2 atoms	=	1·5	or per cent.	4·74
Hydrogen	0·47 or 1 atom	=	0·125	— —	0·40
Bromine	94·21 or 3 atoms	=	30	— —	94·86
	100·00		31·625		100

Thus the constitution of bromoform is precisely the same as that of chloroform; namely, 1 atom bicarburet of hydrogen united to 3 atoms of bromine.

There can be little doubt that the specific gravity of the vapour of bromoform is 8·7847, since it must be a compound of

2 volumes carbon vapour .	= 0·8333
1 volume hydrogen gas .	= 0·0696
3 volumes bromine vapour	= 16·6666
	2)17·5694
	8·7847

united together and condensed into 2 volumes.

SECTION VII.—OF IODOFORM.*

This compound was first observed by Serullas, in the year 1822,† who formed it by dissolving potassium in a solution of iodine in very strong alcohol. Afterwards, he discovered that the same substance might be formed in abundance by mixing together alcoholic solutions of iodine and of potash.‡ It was subjected to chemical analysis by Dumas, in 1834.§

Iodoform is a solid substance, of a sulphur-yellow colour, and crystallizes in plates. It is friable and soft to the touch. It exhales a smell analagous to that of safron. It is tasteless; but its solution in alcohol has a sweet taste. At a temperature lower than that at which paper is charred it is decomposed into iodine, hydriodic acid, and charcoal.

It is but little soluble in water; but dissolves readily in alcohol, from which it is precipitated by water.

The method of obtaining iodoform is to pour an alcoholic solution of potash or soda into an alcoholic solution of iodine till the latter becomes colourless. The whole is then evaporated to dryness, and the dry residue is washed in cold water, which dissolves the iodide of potassium or sodium, and leaves the iodoform. If it be

* This compound is described in my *Inorganic Chemistry* (vol. i. p. 182), under the name of *sesquiodide of carbon*. To that place I refer for its history, as far as British chemists are concerned.

† Ann. de Chim. et de Phys. xx. 165. ‡ Ibid. xxii. 222. § Ibid. lvi. 122.

now dissolved in boiling-hot alcohol it crystallizes when the solution is allowed to cool.

When heated with a solution of potash it melts, and appears to be partly volatilized during the ebullition. The liquid will be found to contain much iodide of potassium and formate of potash.

If we mix it with potassium and heat it in a tube filled with dry azotic gas the potassium melts, becomes incandescent, and at last explodes violently.

Its constituents, as determined by the analysis of Dumas, are as follows:—

Carbon	3·16 or 2 atoms =	1·5	or per cent.	3·06
Hydrogen	0·33 or 1 atom =	0·125	— —	0·26
Iodine	96·51 or 3 atoms =	47·25	— —	96·68
	100·00	48·875		100·00

Or it is composed of 1 atom of bicarburet of hydrogen and 3 atoms of iodine; so that in its constitution it is exactly similar to chloroform and bromoform.

SECTION VIII.—OF CHLORAL.*

This substance was discovered by Liebig, in 1832. Its properties were minutely examined by him, and he subjected it to analysis.† The investigation was continued and extended by M. Dumas, and the analysis repeated in 1834.‡

The most certain method of obtaining chloral is to pass a current of dry chlorine gas through absolute alcohol. But a prodigious quantity of chlorine is necessary, and a great deal of muriatic acid is formed. If we employ an avoirdupois pound of alcohol we shall require 66,453 cubic inches, or almost 38½ cubic feet of chlorine gas, and there will be formed 83,068 cubic inches, or 48 cubic feet of muriatic acid gas.

The chlorine is prepared by mixing together black oxide of manganese, common salt, and sulphuric acid. The vessel into which the mixture of manganese and common salt is put should be of the capacity of almost 12,20 cubic inches, in order that a sufficient quantity of materials to furnish all the chlorine required may be put in at once, so that the operator shall have merely to add sulphuric acid occasionally as it is required. The chlorine gas is received first into an empty Wolfe's bottle, where it cools and deposits a portion of its moisture. It then passes into a second bottle containing chloride of calcium; and then into a third bottle empty and dry, destined to receive the alcohol, should it be absorbed during the process. Finally, the chlorine reaches the bottle containing the alcohol, at the bottom of which it is extricated This bottle terminates in a tube, which conveys the muriatic acid gas formed into the chimney.

At first the chlorine passes rapidly, and is wholly converted into

* This word is formed by joining together the first syllables of the words *chlorine* and *alcohol*.

† Ann. de Chim. et de Phys. xlix. 154. ‡ Ibid. lvi. 125.

muriatic acid. When the action diminishes in intensity, the alcohol assumes a yellow colour. When this happens, heat is applied to the vessel containing the alcohol, and the colour disappears. From this time the alcohol must be kept hot and gradually raised almost to the boiling point, and the process must be continued till the chlorine ceases to act upon the liquid through which it passes.

In 12 hours we may convert 3000 grains of alcohol into chloral. When we operate on 9300 grains or $1\frac{1}{3}$ lb. avoirdupois, the process lasts two or three days.

The liquid remaining in the alcohol bottle is mixed with thrice its bulk of concentrated sulphuric acid, and immediately subjected to cautious distillation in a retort. As soon as this mixture becomes hot, the chloral collects on its surface in the form of a limpid and very fluid oil, which is rapidly volatilized. The process must be stopped when almost the whole of the chloral has passed over.

The product thus obtained is put into a flask with a thermometer, and boiled till the boiling point rises to 201°. What remains is mixed with a fresh quantity of sulphuric acid and distilled again; and then heated till the boiling point rises to 201° as before.

Finally, it is put into a retort along with powder of unslacked lime and distilled over a bath of water saturated with common salt. But care must be taken not to employ too much lime, otherwise the chloral is destroyed or decomposed, the lime towards the end of the process becoming red-hot.

Pure chloral, thus obtained, is a transparent colourless liquid, having an oily feel and staining paper like a fat oil; but the stain in a short time disappears.

Its specific gravity at 64° is 1·502. It boils at 201°, and the density of its vapour is about 5·0.

Its smell is pungent, and it excites tears. It is tasteless, or nearly similar to olive oil in this respect. In an anhydrous state it is very caustic, especially when the skin is exposed to its vapour at the boiling temperature.

It is very soluble in water. When we let some drops of it fall into water it sinks immediately to the bottom in the form of an oil. But, when heat is applied, these drops gradually dissolve and disappear. This solution has no taste, but the characteristic smell of chloral is perceived when we heat the liquid. It does not act as an acid. When nitrate of silver is dropt into it no precipitate appears. Even when the concentrated solution of chloral is boiled with red oxide of mercury no change is perceived.

If instead of heating chloral in water, we bring it in contact with a few drops of that liquid, they combine immediately by agitation with the evolution of heat. And in a short time the compound assumes the form of a white crystalline mass. When a few drops of chloral are let fall into a dry phial filled with humid air, the sides of the phial become speedily coated with minute crystals arranged in stars. These crystals of course constitute a hydrate of chloral.

When chloral is not perfectly pure, but contains a little water, it

becomes muddy after some days, and lets fall a white substance which Liebig has distinguished by the name of *insoluble chloral*. This substance forms most readily when we abandon the chloral to itself, over the sulphuric acid of commerce.

Chloral dissolves iodine, bromine, phosphorus, and sulphur, when assisted by heat. Iodine communicates a fine purple colour.

The anhydrous metallic oxides have no action on chloral. It may be distilled off the oxide of copper, magnesia, or mercury, without experiencing the smallest alteration. It behaves in the same way with anhydrous lime, barytes, and strontian. But when these three last bodies are heated in the vapour of chloral, they decompose it instantly. They become incandescent, carbonic oxide gas is given out, and chlorides of the metals of these bases are formed, mixed with a little charcoal.

When vapour of chloral is passed over red-hot copper or iron, these metals are converted into chlorides, and are at the same time covered with a brilliant coat of porous charcoal.

When the chloral is in the state of a hydrate, or dissolved in water, it is decomposed by the alkaline oxides with the greatest ease and with the disengagement of heat. The colour of the solution is not altered, and no gas is disengaged. Chloroform is formed, and separates while a formate of the alkaline oxide remains in solution.

Nitric acid has no action on chloral, even when heated. We may boil it in chlorine, and expose it to the sun in a flask filled with chlorine without its undergoing any alteration. It merely assumes a yellow colour by dissolving a little chlorine.

Chloral was analyzed with great care by Liebig, and afterwards by Dumas. The following table exhibits the constituents as determined by these accurate experimenters :—

	Liebig.	Dumas.				
Carbon	18·099	16·38	or 4 atoms =	3·0	or per cent.	16·11
Hydrogen	—	0·79	or 1 atom =	0·125	— —	0·67
Chlorine	70·242	72·42	or 3 atoms =	13·5	— —	72·48
Oxygen	11·659	10·41	or 2 atoms =	2·0	— —	10·74
	100·000	100·00		18·625		100·00

Thus it differs from chloroform, by containing 2 more atoms of carbon, and 2 atoms of oxygen.

It was ascertained by Dumas that the density of the vapour of chloral is 5·0. Now the density of

4 volumes carbon vapour .	= 1·6666
1 volume hydrogen gas .	= 0·0694
3 volumes chlorine gas .	= 7·5000
1 volume oxygen gas .	= 1·1111
	2)10·3472
	5·1736

Hence it is obvious that the vapour of chloral consists of 4 volumes

carbon vapour, 1 volume hydrogen gas, 3 volumes chlorine gas, and 1 volume oxygen gas, united together and condensed into 2 volumes.

It has been stated above, that when hydrate of chloral comes in contact with an alkaline base it is decomposed into chloroform and formic acid. Now

Chloral is . .	C^4 H Chl^3 O^2
Chloroform is . .	C^2 H Chl^3
There remains	C^2 O^2
Add an atom of water	H O
and we have	C^2 H O^3

which constitutes an atom of formic acid. Thus it appears that an atom of water being added to an integrant particle of chloral, enables it to resolve itself into chloroform and formic acid.

It has been already stated that chloral dissolves in water, with the disengagement of heat, and that the solution, when evaporated *in vacuo* or spontaneously, crystallizes in rhomboids. These crystals have been subjected to analysis by Dumas, who found them composed of

1 integrant particle chloral .	18·625
1 particle of water . .	1·125
	19·75

This analysis is confirmed by the specific gravity of its vapour, which Dumas found to be 2·76. Now

	Sp. Gravity.
1 volume chloral . . .	5·1736
1 volume vapour of water . .	0·6250
	2)5·7986
	2·8993

Thus the vapour of hydrated chloral is obviously composed of 1 volume chloral and 1 volume vapour of water, united together, and constituting 2 volumes.

Insoluble chloral. It has been already remarked, that Liebig has given the name of *insoluble chloral* to a singular substance which is formed when chloral is left to the action of concentrated sulphuric acid at the ordinary temperature of the atmosphere. It is obtained when we put into a phial, furnished with a ground stopper, chloral and six times its weight of concentrated sulphuric acid, and leave the mixture at rest for 24 hours. The chloral is converted into a white opaque solid substance. After a few days the whole is washed with water, taking care to press the white matter to powder, that it may be more easily washed. It is then thown on a filter, and washed with boiling water till it is deprived of all acid.

Thus obtained it is almost insoluble in water, even when boiling hot. It is equally insoluble in alcohol and ether. When distilled with concentrated sulphuric acid it behaves as chloral, and furnishes a colourless liquid, possessing all the properties of chloral. But in

a few days (as stated by Liebig) this liquid resumes its state of a white opaque insoluble solid. But during the distillation, a little of it seems to be decomposed, for the sulphuric acid blackens, and the liquid distilled contains muriatic acid. When the white substance is heated in a retort, in an oil bath to 300° (or between 300° and 400°), it sublimes without melting, yet the product is liquid, and crystallizes like hydrate of chloral.

It was analyzed both by Liebig and Dumas. The following table exhibits the results obtained :—

	Liebig.	Dumas.				
Carbon	17·686	17·75	or 12 atoms =	9	or per cent.	17·14
Hydrogen	1·166	1·10	or 4 atoms =	0·5	— —	0·95
Chlorine	67·102	67·74	or 8 atom =	36·0	— —	68·58
Oxygen	14·046	13·41	or 7 atoms =	7·0	— —	13·33
	100·000	100·00		52·5		100·00

Now that we are acquainted with the constitution of chloral, it is easy to see what happens during the conversion of alcohol into chloral.

1 atom alcohol is . $C^4 H^6 O^2$
1 atom chloral . $C^4 H Chl^3 O^2$

Hence the alcohol loses 5 atoms of hydrogen, and gains 3 atoms of chlorine. For every atom of alcohol converted into chloral, 10 volumes of muriatic acid are formed, and 3 volumes of chlorine enter into chemical combination with it.

SECTION IX.—OF BROMAL.

This compound, which is obviously analogous to chloral, was discovered by M. Lowig,* in 1832. He obtained it in the following manner :—

He poured bromine into absolute alcohol. A considerable reaction takes place, heat is evolved, and abundance of hydrobromic acid is given out. To the jar in which this mixture is made three Wolfe's bottles are joined; the first empty, the second containing water, and the third an alkaline solution. Between 15 and 20 parts of bromine for 1 part of alcohol are requisite to make the reaction complete. In the empty bottle is found bromal, hydrobromic ether, and a crystalline matter, which is considered to be bromide of carbon. In the bottle containing water, bromal is found mixed with an alcoholic bromal oil. The products of these two bottles are mixed, and agitated with concentrated sulphuric acid, which separates the bromal. In short, the process for purifying the bromal is similar to that described in the last Section for purifying chloral.

Bromal is a colourless liquid, having an oily feel. Its smell is peculiar, and excites tears. Its taste is very sharp and burning. It stains paper like an oil; but the stain disappears when the paper

* Annalen. der Pharmacie, iii. 288.

is exposed to the air. Its specific gravity is 3·34. It may be volatilized without alteration, and its boiling point exceeds 212°. It is soluble in water, and the solution, left to spontaneous evaporation, gives large crystals of hydrate of bromal. It dissolves rapidly in alcohol and ether. Concentrated sulphuric acid deprives hydrate of bromal of its water, and restores it to the state of anhydrous bromal.

Bromal dissolves bromine, sulphur, and phosphorus. The anhydrous alkalies do not alter it; but the hydrous alkalies deprive it of bromine, and convert it into bromoform, while, at the same time, a little formate of the alkali is formed.

It is decomposed by chlorine and fuming nitric acid; but not by muriatic acid, or sulphuric acid. Anhydrous metallic oxides have no action on it; but the hydrated oxides decompose it with the evolution of heat, while metallic bromides, formic acid, and liquid bromide of carbon are formed. When passed over red-hot iron we obtain bromide of iron, charcoal, and carbonic oxide.

Löwig ascertained that 100 parts of bromal contain 84·80 parts of bromine. Now, if we consider its constitution as the same as that of chloral, of which there can hardly be a doubt, the constituents must be

Carbon	8·81 or 4 atoms =	3	or per cent.	8·54
Hydrogen	0·37 or 1 atom =	0·125	— —	0·36
Bromine	84·80 or 3 atoms =	30	— —	85·40
Oxygen	6·02 or 2 atoms =	2	— —	5·70
	100·00	35·125		100

Hydrate of bromal, like hydrate of chloral, is doubtless composed of

1 atom bromal . . .	35·125
1 atom water . . .	1·125
	36·25

It is obtained in crystals when bromal is exposed to the air, or mixed with a little water.

The formation of bromal admits of the same explanation as that of chloral.

SECTION X.—OF ETHAL.*

An account of ethal is given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 332). Since the publication of that work, it has been carefully examined by Dumas and Peligot,† who found it composed of

Carbon	79·2
Hydrogen	14·2
Oxygen	6·6
	100·0

* The word *ethal* is formed by joining together the first syllables of *ether* and *alcohol*.

† Jour. de Pharmacie, xxii. 624. Ann. de Chim. et de Phys. lxii. 5.

Agreeing very nearly with the previous analysis of Chevreul. They consider its constitution to be

16 atoms carbon	= 12	or per cent.	79·34
17 atoms hydrogen	= 2·125	— —	14·05
1 atom oxygen	= 1	— —	6·61
	15·125		100

These atomic numbers may be resolved into 4 $(C^4 + H^4) + H\ O$; that is to say, into 4 atoms of tetarto-carbo-hydrogen, and 1 atom of water. Now, when ethal is mixed with pure phosphoric acid in the state of powder and distilled, we obtain an oily substance much more volatile than ethal, and composed, according to the analyses of Dumas and Peligot of

Carbon	86
Hydrogen	14
	100

This is equivalent to

16 atoms carbon	= 12	or per cent.	85·71
16 atoms hydrogen	= 2	— —	14·29
	14		100

It consists, therefore, of the same number of atoms of carbon and hydrogen, having been deprived of the water by the phosphoric acid. The specific gravity of the vapour of this oily matter was 7·846. Now, the specific gravity of

16 volumes carbon . .	= 6·6666̇
16 volumes hydrogen .	= 1·111i̇
	7·7777̇

It is obvious from this that the oily vapour is composed of 16 volumes carbon vapour, and 16 volumes hydrogen gas united together and condensed into 1 volume. Here, then, we have a compound of 16 atoms carbon, and 16 atoms hydrogen. This new substance has been distinguished by Dumas and Peligot by the name of *cetene*.

It is a colourless oily liquid, which stains paper. It boils at 527°, and may be distilled over unaltered. It is insoluble in water, but very soluble in alcohol and ether, and has no action on vegetable colours. It is tasteless, and burns like the fixed oils with a white flame.

When ethal is placed in contact with sulphuric acid no action takes place, unless heat be applied; but when the mixture is heated over the water-bath and frequently agitated, the two substances combine, and form *sulphocetic acid*. When this compound is dissolved in alcohol, and saturated with potash dissolved in alcohol, sulphate of potash is deposited, and sulphocetate of potash remains in solution with an excess of ethal. When the liquid is filtered and evaporated, the sulphocetate crystallizes. It is to be dissolved in

absolute alcohol, and crystallized a second time. This frees it from sulphate of potash, but it still retains ethal, from which it is freed by reducing it to powder, and digesting it in ether. Thus purified, it is in pearly-white scales. This salt was analyzed by Dumas and Peligot, who found it composed of

32 atoms carbon	= 24	or per cent.	53·28
33 atoms hydrogen	= 4·125	— —	9·14
1 atom oxygen	= 1	— —	2·21
1 atom sulphate of potash	= 11	— —	24·31
1 atom sulphuric acid	= 5	— —	11·06
	45·125		100

These numbers are resolvable into

2 atoms sulphuric acid .	= 10
1 atom potash . . .	= 6
2 atoms cetene . . .	= 28
1 atom water . . .	= 1·125
	45·125

So that the basis of sulphocetic acid appears to be a hydrate of cetene, composed of 2 atoms cetene, and 1 atom water.

When equal volumes of ethal and perchloride of phosphorus in fragments are put into a retort, they act upon each other with considerable violence. The mixture melts, becomes hot and boils, and a great deal of muriatic acid is disengaged. When the retort is heated, after the action is at an end, there passes over protochloride of phosphorus, then perchloride, and at last muriate of cetene. The product of this distillation is distilled again, with a little perchloride of phosphorus. The liquid obtained is treated with water, which destroys the greater part of the chlorides of phosphorus contained in it, and disengages an oily liquid, which is purified by boiling it five or six times successively with water, and then distilling it off a small quantity of quick lime recently slacked.

This liquid was analyzed by Dumas and Peligot, and found composed of

32 atoms carbon . .	= 24
33 atoms hydrogen . .	= 4·125
1 atom chlorine . .	= 4·5
	32·625

This is resolvable into

2 atoms cetene . . .	C^{32} H^{32}
1 atom muriatic acid . .	H Ch

The liquid is, therefore, a muriate of cetene.

MM. Dumas and Peligot consider spermaceti as a compound or mixture of margarate and binoleate of cetene and water. Its constition, they think, is as follows :—

2 atoms margaric acid	$C^{70}\ H^{64}\ O^{6}$
2 atoms oleic acid .	$C^{70}\ H^{60}\ O^{5}$
3 atoms cetene . .	$C^{48}\ H^{48}$
3 atoms water . .	$H^{3}\ O^{3}$
	$C^{188}\ H^{175}\ O^{14}$

Or,

2 atoms margarate of cetene	$C^{102}\ H^{96}\ O^{6}$
1 atom binoleate of cetene	$C^{86}\ H^{76}\ O^{5}$
3 atoms water . .	$H^{3}\ O^{3}$
	$C^{188}\ H^{175}\ O^{14}$

In p. 307, the relation of aldehyde and several similar compounds to the base aldehyden has been shown. Chloroform, bromoform, and iodoform, have for their base bicarburet of hydrogen, or $C^{2}\ H$.

Thus bicarburet of hydrogen	$C^{2}\ H$
Chloroform . .	$C^{2}\ H + Chl^{3}$
Bromoform . . .	$C^{2}\ H + Br^{3}$
Iodoform . . .	$C^{2}\ H + Iod^{3}$
Chloral and bromal have for a base	$C^{4}\ H\ O^{2}$ or 2 $(C^{2}\ H)$
Thus chloral is . . .	$C^{4}\ H\ O^{2} + Chl^{3}$
Bromal . . .	$C^{4}\ H\ O^{2} + Br^{3}$

CHAPTER II.

OF ETHERS.

It has been already stated that sulphuric ether consists of $C^{4}\ H^{5}\ O$, and that it possesses the characters of a base, being capable of neutralizing various (probably all) acids and supporters of combustion. These new compounds are at present very inaccurately termed *ethers*.

Thirteen of these ethers have been already described in the *Chemistry of Inorganic Bodies*. Since the publication of that work, the action of acids on alcohol has been very much investigated. The consequence has been the discovery of many new ethers, and the rectification of our ideas respecting some of those previously known. I propose to state these new facts in the present Chapter.

I. The base of ether is $C^{4}\ H^{5}$, a substance not yet obtained in a separate state, but to which Liebig has given the name of *ethyl*. But several of its compounds, with simple bodies, have been accurately examined. The following are the most important of these:—

1	Oxide of ethyl, or common ether .	$C^4 H^5 O$
2	Chloride of ethyl, or muriatic ether	$C^4 H^5 Chl$
3	Bromide of ethyl, or hydrobromic ether	$C^4 H^5 Br$
4	Iodide of ethyl, or hydriodic ether	$C^4 H^5 Iod$
5	Sulphuret of ethyl, or mercaptan .	$C^4 H^5 S+H S$
6	Cyanodide of ethyl, or hydrocyanic ether	$C^4 H^5 (C^2 Az)$
7	Sulphohydric ether . . .	$C^4 H^5 (H S)$?

Several of these compounds have been described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 295), though the view of the constitution given in that work is not always correct.

1. Common ether, described *Ibid.* vol. ii. p. 295.
2. Muriatic ether, *Ibid.* p. 310.
3. Hydrobromic ether, *Ibid.* p. 314.
4. Hydriodic ether, *Ibid.* p. 315.
5. Mercaptan and the two other bodies have been discovered since the publication of that work. We shall, therefore, give an account of them here.

SECTION I.—OF MERCAPTAN.

This name has been given by M. Zeise, professor of Chemistry, at Copenhagen, to a new compound which he discovered about the year 1833, and which he called *mercaptan*, on account of the energy with which it acts on the red oxide of mercury.*

M. Zeise obtained mercaptan by the following process:—A quantity of althionate of barytes, lime, or potash, was heated in a concentrated solution of the protosulphuret of barium. The process was conducted in a distilling apparatus. There distilled over along with the water an ethereal liquid, while the althionate was changed into sulphate. And, if the proportions of althionate and sulphuret were such, that each contained an atom of metal, the decomposition of both was complete, and nothing remained in the retort but neutral sulphate. Hardly any sulphuretted hydrogen was disengaged in the state of gas; and neither the water nor the ethereal liquid contained any considerable quantity of it.

The ethereal liquid thus obtained was lighter than water. When separated mechanically from the water with which it had condensed in the receiver, then freed from the adhering sulphuretted hydrogen by agitation in water, and finally freed from water by means of chloride of calcium, it exhibited the following properties:—

It was a colourless liquid, with an exceedingly penetrating odour, having some analogy at once to that of assafœtida and garlic. Its taste was sweet. It inflamed readily, giving out the odour of sulphurous acid.

When this liquid was distilled it was divided into two distinct liquids. To the first of these Zeise give the name of *thialic ether;* to the second, that of *mercaptan*.

* It signifies, he says, *corpus mercurium captans*. See Ann. de Chim. et de Phys. lvi. 87.

The thialic ether constitutes the greatest portion of the produce. It is not affected by an alcoholic solution of a salt of lead. It does not act on the red oxide of mercury, and has very little action on potassium. According to Zeise, it is composed of sulphur, carbon, hydrogen, and oxygen, in proportions still undetermined.

The mercaptan is obtained in greater abundance when, in the preceding process, the deutosulphuret of barium is substituted for the protosulphuret.

Liebig* has given the following process for obtaining mercaptan in a state of purity :—

A solution of potash of the specific gravity 1·28 or 1·30, is saturated with sulphuretted hydrogen, and mixed with an equal volume of a solution of althionate of lime of a similar specific gravity. This mixture is to be distilled over the water-bath, and the receiver, during the process, must be kept very cool. The product of the distillation is rectified over mercaptide of mercury (see below), and finally freed from water by chloride of calcium. It is now pure.

Mercaptan thus obtained is a colourless liquid, which does not congeal when cooled down to —8°. Its smell is peculiar, though it has some analogy to that of garlic, and exceedingly penetrating. Its taste is at once sweet and ethereal. Its specific gravity at 59° is 0·842 according to Zeise, 0·837 according to Liebig. Its boiling point, according to Zeise, is 144°; but according to Liebig, only 97°.

It is very little soluble in water. In alcohol and ether it dissolves in almost all proportions. It has no sensible action on vegetable colours.

The solution of mercaptan gives, with acetate of lead, a copious lemon-yellow precipitate, but it does not act on nitrate of lead. When poured on red oxide of mercury it attacks that oxide with violence, changing it into a white crystalline body, while at the same time water is formed. The same substance is formed when mercaptan is placed in contact with corrosive sublimate, and muriatic acid is produced. It exerts an analogous action on the perchloride of gold. Black oxide of copper is slowly converted by it into a colourless powder.

Mercaptan acts at the ordinary temperature with considerable force upon potassium, hydrogen gas being evolved, and the metal converted into a colourless salt, very soluble in water and in alcohol. These solutions give a yellow precipitate, with acetate and nitrate of mercury. They precipitate corrosive sublimate, and chloride of gold and copper. When the crystalline body produced by the action of mercaptan on corrosive sublimate is exposed dry to the action of sulphuretted hydrogen in the gaseous state, mercaptan and cinnabar are formed, and nothing else.

M. Zeise analyzed this white crystalline body into which red oxide of mercury is changed by mercaptan, and found it composed of

* Annal. der Pharm. xi. 14.

4 atoms carbon . . .	=	3
5 atoms hydrogen . .	=	0·625
2 atoms sulphur . .	=	4
1 atom mercury . .	=	12·5
		20·125

Zeise subjected mercaptan itself to an analysis, and found its constituents

4 atoms carbon . . .	3
6 atoms hydrogen . . .	0·75
2 atoms sulphur . . .	4
	7·75

The analysis was repeated by Liebig with the same result. Thus the difference between mercaptan and the white mercurial substance is, that in the former an atom of hydrogen replaces an atom of mercury in the latter.

Zeise considers C^4 H^5 S^2 as the base of this substance, which he calls *mercaptan*.* But it is simpler to view the base as ethyl, and to consider mercaptan as a sulphuret of ethyl or C^4 H^5 S united to an atom of sulphuretted hydrogen. Mercaptan is a hydrate of this substance, and he proposes to call it *hydromercaptum*. The white mercurial substance he calls *mercaptide of mercury*.

Zeise analyzed the mercaptide of gold, and found it composed of

1 atom mercaptan . .	C^4 H^5 S^2
2 atoms gold . . .	Au^2

Or better, C^4 H^5 S + Au^2 S.

Mercaptide of platinum is C^4 H^5 S^2 + Pl. The mercaptide of mercury melts at 187°. The mass, after congealing, resembles chlorate of potash after it has been fused. It is without smell, but emits a peculiar odour when rubbed. At the temperature of 257° it begins to deposit mercury. At 347° it is completely decomposed, giving out, among other things, an oil resembling thialic oil.

Mercaptide of mercury is insoluble in water, and but little soluble in alcohol. It may be melted in a concentrated solution of potash without undergoing any alteration. The acids scarcely act upon it at the ordinary temperature, except nitric acid.

Mercaptide of gold is an amorphous mass without lustre and colourless. With water, alkalies, and acids, it behaves nearly as the mercaptide of mercury. It may be heated to 428° without any sensible alteration. When distilled at a somewhat higher temperature, it gives a peculiar oily substance, without disengagement of gas. Gold remains apparently pure.

Mercaptide of platinum when distilled is transformed into sulphuret of platinum, exhibiting, at the same time, the phenomenon of ignition.

* *Corpus mercurio aptum.*

Mercaptides of potassium and sodium have always an alkaline reaction. When dry, they support a temperature of 212° without alteration. But when their aqueous solution is heated it is easily altered.

SECTION II.—OF CYANODIDE OF ETHYL, OR HYDROCYANIC ETHER.

This ether was discovered by M. Pelouze, in 1834.* It may be obtained by heating gently a mixture of equal parts of cyanodide of potassium and althionate of barytes. The liquid which distils over is to be mixed with from four to five times its bulk of water to wash away the alcohol and hydrocyanic acid which it may contain. It is kept afterwards for some time at a temperature between 140° and 160°, and finally distilled over chloride of calcium.

It is a colourless liquid, having a very strong alliacious odour. Its specific gravity is 0·78. It boils at 179°½. Water is a very bad solvent of it; but alcohol and ether dissolve it in any proportion. It acts with great energy on the animal economy. When pure it does not precipitate nitrate of silver. Potash ley decomposes it with great difficulty, and only when much concentrated. Its constituents, according to the analysis of Pelouze, are

6 atoms carbon . . .	= 4·5
5 atoms hydrogen . .	= 0·625
1 atom azote . . .	= 1·75
	6·875

We may consider it as a compound of

1 atom cyanogen . . .	C^2 Az
1 atom ethyl . . .	C^4 H^5

SECTION III.—OF SULPHOHYDRIC ETHER.

This ether was formed by M. Löwig,† in 1836, by the following process:—Oxalic ether was mixed with sulphuret of potassium, prepared by decomposing sulphate of potash by means of charcoal. The sulphuret was reduced to a fine powder, and while still hot, it was introduced into a retort, and pure oxalic ether poured over it till the whole formed a thick mucilaginous mass. This mixture was exposed for some hours to a moderate heat, taking care to avoid all contact of water. The heat was then increased, and the distillation continued till the oxalate of potash formed began to be decomposed.

The product of this distillation consisted of a mixture of sulphohydric ether, and oxalic ether. It was agitated for a considerable time with a concentrated solution of pure potash, or of sulphuret of barium, which decomposed the oxalic ether. The sulphohydric ether thus purified, was decanted and rectified over chloride of calcium. Its purity was ascertained by agitating it in a solution of sulphuret of barium. It occasioned no precipitate in that liquid.

* Jour. de Pharm. xx. 399. † Poggendorf's Annalen, xxxvii. 550.

Sulphohydric ether is lighter than water and has an ethereal, but very disagreeable odour of assafœtida. A single drop is sufficient to spread this smell over a large space. Its taste is sweet. It has no action on vegetable blues. It is little soluble in water, but it communicates to that liquid its taste and its smell. It may be mixed in all proportions with alcohol and ether. It burns with a blue flame, disengaging sulphurous acid. It is not altered by exposure to the air. When boiled with an aqueous solution of potash, it is not decomposed. But if we distil it off hydrate of potash in fine powder, we obtain sulphuret of potassium and alcohol. But this decomposion goes on slowly, and a great part of the ether is disengaged without decomposition. Potassium decomposes it when assisted by a moderate heat; but the decomposition soon stops, because the sulphuret of potassium formed covers the potassium remaining in a crust, and thus hinders any farther action. No hydrogen gas is disengaged during this decomposition.

Sulphohydric ether has no action on red oxide of mercury, and by this character it is easily distinguished from *mercaptan*. Yet it precipitates some heavy metallic salts. Thus it throws down the alcoholic solution of acetate of lead yellow. When mixed with a concentrated alcoholic solution of sulphuret of potassium, a white substance is precipitated, having considerable resemblance to mercaptate of potassium of Zeise.

Probably this ether might be obtained also by distilling a mixture of sulphuret of potassium and dry althionate of barytes.

II. The next set of bodies to which the term ether has been applied, are in fact not ethers, but ought to constitute a different class of bodies. Their base is not $C^4 H^5$ but $C^4 H^4$ or tetartocarbo-hydrogen. They are the following:—

1	Light oil of wine .	$C^4 H^4$
2	Chloric ether .	$C^4 H^4 + Chl^2$*
3	Bromic ether .	$C^4 H^4 + Br^2$
4	Iodic ether . .	$C^4 H^4 + Iod^2$
5	Acetal . . .	$C^4 H^4 + H^3 O$
6	Sulphocyanic ether	

III. The third set of bodies classed among the ethers, consists of chemical compounds of sulphuric ether and an acid. Ether (*sulphuric ether*) possesses the characters of a *base* and probably neutralizes all acids. But the only compounds of this kind hitherto examined are the following:—

1	Nitric ether .	$C^4 H^5 O + Az O^3$
2	Carbonic ether .	$C^4 H^5 O + C O^2$
3	Oxalic ether .	$C^4 H^5 O + C^2 O^3$
4	Formic ether .	$C^4 H^5 O + C^2 H O^3$
5	Succinic ether .	$C^4 H^5 O + C^4 H^2 O^3$

* See Chemistry of Inorganic Bodies, ii. 323.

6	Acetic ether .	$C^4 H^5 O + C^4 H^3 O^3$
7	Benzoic ether .	$C^4 H^5 O + C^{14} H^5 O^3$
8	Malic ether .	$C^4 H^5 O + C^4 H^2 O^4$
9	Citric ether .	$C^4 H^5 O + C^4 H^2 O^4$
10	Tartaric ether .	$C^4 H^5 O + C^4 H^2 O^5$
11	Mucic ether .	$C^4 H^5 O + C^6 H^4 O^7$
12	Pyrocitric ether .	$C^4 H^5 O + C^5 H^2 O^3$
13	Pyrotartaric ether	$C^4 H^5 O + C^5 H^3 O^3$
14	Pyromucic ether .	$C^4 H^5 O + C^{10} H^3 O^5$
15	Suberic ether .	$C^4 H^5 O + C^8 H^6 O^3$
16	Ænanthic ether .	$C^4 H^5 O + C^{14} H^{13} O^2$
17	Chlorocarbonic ether	$C^4 H^5 O + C^2 Chl O^3$
18	Cyanic ether .	$C^4 H^5 O + 2(C^2 Az O) + 3(H O)$
19	Chlorocyanic ether	$C^4 H^5 O + C^2 Az Chl$
20	Elaidic ether .	$C^4 H^5 O + C^{35} H^{33} O^3$

Such of these salts, improperly called ethers, as have not been inserted in the *Chemistry of Inorganic Bodies*, will be described in the following Sections.

SECTION I.—OF NITRIC ETHER.

Described in the *Chemistry of Inorganic Bodies* (ii. 317).

SECTION II.—OF CARBONIC ETHER.

This ether was discovered by Dr Ettling in 1836.* M. Löwig of Zurich had announced, that when potassium or sodium is made to act on oxalic ether, the ether is decomposed into oxalic acid, croconic acid, carbonic oxide gas, and sulphuric ether. M. Ettling repeated the experiments of Löwig, but obtained very different results. No croconic acid was formed, but a red resinous-looking substance, soluble in alcohol, ether and water. The ether produced, instead of being sulphuric, he found to be carbonic ether. The process followed was this:—

A fragment of sodium was put into anhydrous oxalic ether exempt from oil of wine. No action was observed while the liquid was cold; but when heat enough was applied to soften the sodium, it separated from the crust of oxide with which it was environed when introduced into the liquid. Then yellowish white flocks were formed round the sodium, which gradually deepened in colour, and at last assumed a dirty-red tinge. The sodium appeared brilliant and no gas was given off. But when the temperature was raised to 266°, gas began to issue from the sodium. When this matter was collected, it measured 45·7 cubic inches from 100 grains of oxalic ether. The properties of this gas were similar to those of carbonic oxide, but from the analysis of Ettling, by means of oxide of copper, it seems to have been a mixture of 12·6 volumes of carbonic oxide, and 1 volume of hydrogen gas.

When new pieces of sodium introduced occasioned no farther

* Jour. de Pharmacie, xix. 17.

evolution of gas, the matter in the retort had a deep-red colour, a syrupy consistence while hot, but almost solid when cold, and possessing a peculiar smell. It was completely soluble in absolute alcohol, and when dried *in vacuo*, over sulphuric acid, formed a mass having a glossy lustre. When reduced to powder, it had a reddish-brown colour, and was very easily moistened and agglutinated together.

When the mass before being dried was put into water, it dissolved readily, and the new ether separated and swam on the surface of the liquid. It was washed with water, and then distilled with a new portion of water. When it still contained oxalic ether undecomposed, it was rectified on a small quantity of sodium, after having been previously deprived of water by digestion with chloride of calcium. Finally, it was heated in a small retort till its boiling point became constant, in order to deprive it of any alcohol that it might contain. Thus purified, it possessed the following properties:—

It is a colourless and very fluid substance. Its specific gravity is 0·976 at 66°. It boils at 257°. It burns with difficulty at the end of a glass rod with a small blue flame. Its taste is hot and aromatic, its smell cooling, having some resemblance to that of oxalic ether.

When mixed with an alcoholic solution of caustic potash, no action is observed while the mixture is cold, but when a slight heat is applied it becomes muddy, and a white bulky precipitate falls, which, when a very little water is added, unites into drops of oil at the bottom of the liquid. The addition of an acid occasions then a lively effervescence, by the evolution of carbonic acid gas. The liquid after being neutralized shows no trace of oxalic acid; nor is any formic acid shown when salts of silver or mercury are added to the liquid.

It was analyzed by Ettling, and found composed of

Carbon	50·25 or 5 atoms	= 3·75	or per cent.	50·85
Hydrogen	8·52 or 5 atoms	= 0·625	— —	8·47
Oxygen	41·23 or 3 atoms	= 3·00	— —	40·68
	100·00	7·375		100

These numbers may be resolved into

1 atom sulphuric ether .	$C^4 H^5 O$
1 atom carbonic acid .	$C O^2$
	$C^5 H^5 O^3$

M. Ettling determined the specific gravity of the vapour of this ether and found it 4·243. Now the weight of

1 volume ether vapour is .	2·5694
1 volume carbonic acid gas .	1·5277
	4·0972

We see from this that carbonic ether is a compound of 1 volume ether vapour, and 1 volume carbonic acid gas united together and condensed into 1 volume.

SECTION III.—OF OXALIC ETHER.

This ether has been described at sufficient length in the *Chemistry of Inorganic Bodies* (vol. ii. p. 322). We introduce it here to explain the nature of the following compounds :—

1. *Oxamethane.* M. Dumas* passed a current of dry ammoniacal gas over a given quantity of pure oxalic ether. The matter being solidified, it was heated, and the current of gas continued for some time longer. The substance thus obtained he called *oxamethane.* 100 ether treated in this manner furnished 76 or 77 of oxamethane.

It melts at a temperature below 212°, but is not volatilized under 428°. When sublimed it crystallizes in beautiful radiated plates. It dissolves in alcohol, without alteration. When put into water that liquid becomes very acid, and probably alcohol and binoxalate of ammonia are formed. It was analyzed by Dumas and Boullay indirectly, and afterwards directly by Dumas, with the following result :—

Carbon	40·725
Hydrogen	5·990
Azote	12·345
Oxygen	40·940
	100·000

It was analyzed by Mitscherlich with the same result.† The mean of both analyses is

Carbon	41·50 or 8 atoms	= 6	or per cent.	41·02
Hydrogen	6·06 or 7 atoms	= 0·875	— —	5·99
Azote	11·81 or 1 atom	= 1·75	— —	11·97
Oxygen	40·63 or 6 atoms	= 6·00	— —	41·02
	100·00	14·625		100

These atoms may be resolved into

2 atoms oxalic acid .	$C^4\ O^6$
1 atom ether . .	$C^4\ O\ H^5$
1 atom ammonia .	$H^3\ Az$
	$C^8\ O^7\ H^8\ Az$
Minus 1 atom water .	$O\ H$
	$C^8\ O^6\ H^7\ Az$

So that it wants an atom of water in order to be a compound of one integrant particle of oxalic ether, and one integrant particle of oxalate of ammonia. It is therefore a compound of oxamide and oxalic ether. Hence the reason why by Mitscherlich it is denominated *etheroxamide.*

2. *Etheroxalate of potash.* It was shown by Liebig that oxalic ether has the property of combining with bases like an acid. Mitscherlich has analyzed the etheroxalate of potash, and found it composed of

* Ann. de Chim. et de Phys. liv. 241; and Liebig, Annalen der Pharmacie, ix. 129.

† Poggendorf's Annalen, xxxiii. 333.

Carbon	31·16 or 8 atoms	= 6	or per cent.	30·57
Hydrogen	3·17 or 5 atoms	= 0·625	— —	3·18
Oxygen	35·65 or 7 atoms	= 7	— —	35·67
Potash	30·02 or 1 atom	= 6	— —	30·88
	100·00*	19·625		100

These may be resolved into

2 atoms oxalic acid . .	C^4	O^6
1 atom sulphuric ether .	C^4 H^5	O
	C^8 H^5	O^7

united with an atom of potash.

According to Mitscherlich, this salt is obtained when oxalic ether is dissolved in absolute alcohol, and as much hydrate of potash previously dissolved in obsolute alcohol is added as is just sufficient to neutralize half the oxalic acid contained in the ether.† If more potash be added, the oxalic ether is decomposed.

The salt being insoluble in alcohol, precipitates in crystalline plates. They are to be collected on a filter, and washed with absolute alcohol, and then dissolved in hydrous alcohol, which will leave undissolved any oxalate of potash that may be mixed with the ether salt. We obtain the etheroxalate of potash by exposing this solution to spontaneous evaporation, it falls, though with difficulty, in crystals. It is exceedingly easily decomposed. The addition of even a weak base, or a salt of lime, or a metallic oxide, as oxide of cobalt, lead, or copper, occasions always the formation of a metallic salt and the separation of the ether in the state of alcohol. The best way to combine the acid of this salt with other bases, is to precipitate the solution of the salt in hydrous alcohol with sulphuric acid, and to saturate the acid thus set free with carbonate of barytes, or carbonate of lime. If we evaporate the solution to the consistence of a syrup, we obtain the salts with these bases in crystals. These may be decomposed by neutral sulphates, and thus other etheroxalates obtained. If we attempt to saturate the free acid of etheroxalate of potash with oxide of copper, we obtain nothing but an oxalate. The acid cannot be obtained in a concentrated state either by evaporating it on the water-bath, or *in vacuo*. The solution thus treated shoots into crystals of oxalic acid.

SECTION IV.—OF FORMIC ETHER.

Described in *Chemistry of Inorganic Bodies* (vol. ii. p. 330).

SECTION V.—OF SUCCINIC ETHER.

M. J. d'Arcet‡ has discovered an ether of succinic acid. It may be obtained by mixing together 10 parts of succinic acid, 20 parts alcohol, and 5 parts of concentrated muriatic acid, and distilling

* Poggendorf's Annalen, xxxiii. 332. † Lehrbuch der Chim. 2 Aufl. i. 644.
‡ Jour. für pract. Ch. iii. 213.

the mixture. What passes over is to be returned back into the retort and distilled again, and this process must be several times repeated. At last an oily-looking body will be observed in the retort, which, when treated with water, gives out succinic ether. It is washed with cold water in a retort, containing a thermometer, and it is to be gradually heated, but not to the boiling point. Oxide of lead is now added, and the ether distilled off.

It is a colourless transparent liquid, not unlike benzoic ether, and when burnt has a sour smell like it. It has an oily feel; a specific gravity of 1·036, and boils when heated to 417°. According to the analysis of d'Arcet it is composed of

1 atom ether . . .	$C^4 H^5 O$
1 atom succinic acid .	$C^4 H^2 O^3$
	$C^8 H^7 O^4$

When boiled with potash it is decomposed, and alcohol passes over. The vapour of this ether has a specific gravity of 6·22 at the temperature of 32°, and when the barometer stands at 29·92 inches. Now, the specific gravity of

8 volumes	carbon	= 3·3333
7 —	hydrogen	= 0·4861
2 —	oxygen	= 2·2222
		6·0416

It is evident from this that these 7 volumes of gaseous matter are condensed in the vapour of ether into 1 volume.

Chlorine decomposes this ether by the assistance of light, and succinic acid is separated in crystals.

SECTION VI.—OF ACETIC ETHER.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 325) I have given an account of this ether, and have stated its composition according to the analysis of Dumas and Boullay. It has been since subjected to a new analysis by Liebig, who prepared it by distilling a mixture of

16 parts anhydrous acetate of lead,
5 parts sulphuric acid,
4½ parts of absolute alcohol.

He got from this mixture six parts of acetic ether. This ether was deprived of all water by digestion with chloride of calcium, and analyzed. Liebig obtained

Carbon	53·60
Hydrogen	9·68
Oxygen	36·72
	100·00*

This gives the formula

* Annalen der Pharmacie, v. 34.

8 atoms carbon	= 6	or per cent.	54·54
8 atoms hydrogen	= 1	— —	9·09
4 atoms oxygen	= 4	— —	36·37
	11		100·00

These atoms are obviously resolvable into

1 atom sulphuric ether .	$C^4 H^5 O$
1 atom acetic acid . .	$C^4 H^3 O^3$
	$C^8 H^8 O^4$

SECTION VII.—OF BENZOIC ETHER.

See *Chemistry of Inorganic Bodies* (vol. ii. p. 328).

SECTION VIII.—OF MALIC ETHER.

See *Chemistry of Inorganic Bodies* (vol. ii. p. 331).

SECTION IX.—OF CITRIC ETHER.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 331) I gave a very short account of citric ether, which had been discovered by Scheele, and examined by Thenard. It has been lately examined with great care, and subjected to a rigid analysis by M. Malagutti. His method of preparing it was nearly the same as that of Thenard. He put into a retort

90 parts citric acid crystals,
110 parts alcohol of specific gravity 0·814,
50 parts of concentrated sulphuric acid.

The citric acid and alcohol were first introduced, and the sulphuric acid was added by small portions at a time. The temperature was gradually raised to the boiling point, and the distillation was stopped when the liquid in the receiver amounted to about $\frac{1}{3}$ of the bulk of the alcohol employed. The residual liquid was now taken out of the retort and mixed with twice its volume of distilled water. An oily matter collected at the bottom of the liquid: this was the citric ether. It was washed several times with cold water, and then with water containing a little alkali, till the water came off quite pure. It was then dissolved in alcohol, and the solution digested with animal charcoal. The solution was then evaporated on the water-bath, and the ether finally dried *in vacuo* over sulphuric acid.*

When the quantity of citric acid employed amounted to half a pound the quantity of citric ether obtained was about 221 grains, or about $\frac{1}{17}$ of the weight of the acid.

Pure citric ether is a transparent, yellowish, oily-looking liquid. Its smell has some resemblance to that of olive oil. Its specific gravity is 1·142. It is volatile, but the point of volatilization approaches so nearly that of decomposition that it cannot be distilled over without destroying the greatest part of it. It begins to lose its

* Ann. de Chim. et de Phys. lxiii. 201.

limpidity at 248°. It becomes red at 518°. It begins to boil and to be decomposed at 541°½, a brown oily matter passing over. Soon after, water containing alcohol passes over, and, finally, carburetted hydrogen and citric ether. A quantity of charcoal remains in the retort.

Citric ether is neutral, and, when burnt, leaves no residue. It is soluble in ether, in alcohol, even though weak, and a little soluble in water. An aqueous solution of it becomes acid by keeping, and the change is more rapid when heat is applied. If we boil citric ether with a solution of potash or soda, we obtain alcohol and citrate of potash or soda. Liquid ammonia has no immediate action, but, by degrees, it acts like potash or soda. Ammoniacal gas has no action whatever. Barytes and strontian water do not precipitate a recent aqueous solution of citric ether. Cold nitric acid dissolves this ether, and when the solution is mixed with water the ether does not separate. When the solution is slightly heated a lively action takes place; red vapours are disengaged, and the residue has the smell of hyponitrous ether. If the heat be long continued and the quantity of ether considerable, oxalic acid is formed.

Concentrated sulphuric acid immediately deepens the colour of citric ether. The acid dissolves the ether without the assistance of heat, but, when water is added to the solution, the ether separates again unaltered. When the sulphuric solution of the ether is heated to 158° a reaction commences, and becomes more violent as the temperature is raised: alcohol and sulphuric ether are disengaged, and a thick transparent matter remains which is soluble in water.

Cold muriatic acid dissolves citric ether and separates from it again when diluted with water. When the solution is heated sufficiently muriatic ether is disengaged, together with a little alcohol, and no citric ether is found in the residue.

When potassium is placed in contact with citric ether gas is disengaged, but it stops as soon as the surface of the metal becomes oxidized. Citric ether dissolves iodine and bromine. When the solution of bromine is heated all the bromine is disengaged and the residue is acid. But the solution of iodine does not lose its iodine nor become acid when heated.

Citric ether was analyzed by M. Malagutti, by passing it through red-hot oxide of copper. He obtained

Carbon	50·40
Hydrogen	7·31
Oxygen	42·29
	100·00

Now, these numbers correspond with

8 atoms carbon	= 6	or per cent.	50·74
7 atoms hydrogen	= 0·825	— —	6·97
5 atoms oxygen	= 5·0	— —	42·29
	11·825		100·00

But

1 atom citric acid is	.	$C^4 H^2 O^4$
1 atom sulphuric ether	.	$C^4 H^5 O$
		$C^8 H^7 O^5$

It is obvious from this that citric ether is a compound of 1 atom citric acid, and 1 atom sulphuric ether. So that it agrees in its constitution with all the other acid ethers.*

SECTION X.—OF TARTARIC ETHER.

See *Chemistry of Inorganic Bodies* (vol. ii. 231).

SECTION XI.—OF MUCIC ETHER.

This very curious ether was discovered and examined by M. Malagutti, chemist to the Porcelain Manufactory at Sevre, in 1836.† He obtained it in the following way :—

One part of mucic acid was mixed with 4 parts of sulphuric acid, and the mixture gently heated. It became first of a delicate red colour, then crimson, and the colour gradually deepened till it became black. It was taken from the fire, hermetically sealed, and after an interval of 12 hours was mixed with 4 parts of alcohol of 0·814, and the whole was left at rest for 24 hours. The whole had now become solid. To remove it from the vessel alcohol was poured in, it was briskly agitated, and then thrown upon a filter. To render it quite pure it was repeatedly dissolved in boiling alcohol, from which it was deposited on cooling in a crystallized state.

The crystals are right four-sided prisms. At first they appear tasteless, but they leave an impression of bitterness in the mouth. They melt at 336°½, and when cooled down to 275°, congeal into a crystalline mass. Just before melting, a little brownish oily liquid is discharged from them. If after the fused crystals have solidified, we allow the temperature to sink to 158°, and then raise it again, fusion takes place at the temperature of 302°. At 338° the matter blackens, and is decomposed. The products of the decomposition are alcohol, water, carbonic acid, pyromucic acid partly crystallized on the upper part of the retort, acetic acid, carburetted hydrogen, and charcoal.

The specific gravity of crystallized mucic ether is 1·17. It is insoluble in ether, very soluble in boiling, though but little soluble in cold alcohol. 1000 parts of alcohol of 0·814, at the temperature of 60° dissolve only 6·4 parts of mucic ether. It is very soluble in boiling water, and the solution, on cooling, deposits large crystals, having the form of right oblique four-sided prisms, two of the opposite faces being usually much broader than the other two. These crystals have a specific gravity of 1·32. 100 parts of water at 59° dissolve 2·27 of them. They melt at 336°½, and the fused mass concretes again when cooled down to 251°½. If we sink the temperature to 158°,

* Ann. de Chim. et de Phys. lxiii. 197. † Ibid. 86.

and then heat again, the solid matter assumes the consistence of butter at 212°, and melts at 266°; while the crystals obtained from an alcoholic solution become solid at 275°, and melt again at 302°. With the exception of this difference of the melting and congealing points, the properties of these two sets of crystals are the same.

Lime, barytes, or strontian water decomposes mucic ether, throwing down a mucate. Potash and soda, when boiled with it, decompose it also, alcohol being disengaged. It is decomposed also by long boiling.

When a current of ammoniacal gas is passed over melted mucic ether, no action takes place; but if the temperature be raised to 338°, alcohol is disengaged, carbonate of ammonia formed, together with a very aromatic oil, which, when agitated for some time in water, dissolves, communicating a yellow colour to the liquid.

Nothing remarkable takes place when a current of chlorine gas is passed over the melted ether. But on cooling, the solid mass (which is not crystallized) is transparent, and coloured like amber, and has become very soluble in alcohol. When nitrate of silver is dropt into the alcoholic solution, no precipitate appears.

M. Malagutti analyzed mucic ether by means of oxide of copper. The mean of four experiments gave

Carbon	45·01
Hydrogen	6·87
Oxygen	48·12
	100

These numbers give us the atomic constitution as follows:—

10 atoms carbon	= 7·5	or per cent. 45·11
9 atoms hydrogen	= 1·125	— — 6·77
8 atoms oxygen	= 8·0	— — 48·12
	16·625	100

Now, mucic acid is $C^6 H^4 O^7$. If we subtract this from mucic ether . . . . . $C^{10} H^9 O^8$

$C^6 H^4 O^7$

There will remain . . $C^4 H^5 O$

Which is equivalent to an integrant particle of sulphuric ether. It is clear from this that mucic ether is a compound of

1 atom mucic acid = $C^6 H^4 O^7$
1 atom ether = $C^4 H^5 O$

$C^{10} H^9 O$

These analyses have been confirmed by Liebig and Pelouze.

SECTION XII.—OF PYROCITRIC AND PYROTARTARIC ETHERS.

These ethers were first prepared by M. Malagutti.* They are obtained by the same process as citric ether.

* Ann. de Chim. et de Phys. lxiv. 275.

They are liquid, colourless, and transparent, have a bitter taste, and a weak smell like *calamus aromaticus*. The specific gravity of pyrocitric ether is 1·040, that of pyrotartaric 1·016. They are scarcely soluble in water, but combine in all proportions with alcohol and ether. The first begins to boil at 437°, the second at 424°½; but the temperature rises as the boiling goes on. Potash disengages alcohol, and combines with the acid of the ether.

Pyrocitric ether is composed of

1 atom pyrocitric acid .	$C^5 H^2 O^3$	= 7
1 atom ether . . .	$C^4 H^5 O$	= 4·625
	$C^9 H^7 O^4$	11·625

Pyrotartaric ether of

1 atom pyrotartaric acid .	$C^5 H^3 O^3$	= 7·125
1 atom ether . . .	$C^4 H^5 O$	= 4·625
	$C^9 H^8 O^4$	11·75

SECTION XIII.—OF PYROMUCIC ETHER.

This ether was first made by M. Malagutti, in the year 1836.* The process for making it is to mix together 20 parts of alcohol of 0·814, 5 parts of muriatic acid, and 10 of pyromucic acid. This mixture is to be distilled four or five times, returning the product each time into the retort At the last cohobation the distillation is continued till the liquid which passes over begins to get coloured. Pour water into the product, an oily matter separates, which in a few minutes crystallizes in plates and prisms. Collect the crystals on a filter, wash them with cold water, and dry them by pressure between folds of blotting paper. To have them perfectly pure they must be distilled repeatedly, till they leave no traces of residue in the retort.

It has the form of a rhombic prism, is colourless, transparent, and has a very greasy feel. Smell strong and analogous to that of benzoate of methylene. Taste cooling, sharp and bitter. Specific gravity 1·297. Does not melt at 93°, boils at about 408°, and may be distilled over without leaving any residue. Scarcely soluble in water, but soluble in all proportions in alcohol and ether. It does not catch fire at a candle. Potash and soda decompose it; ammonia produces no effect. Lime, barytes, and strontian water throw down a precipitate redissolved by the addition of a few drops of water. Nitric acid renders it liquid and then decomposes it. Sulphuric and muriatic acids dissolve without decomposing it, unless heat be applied.

This ether was analyzed by M. Malagutti, and found composed of

		Atomic weight.
1 atom pyromucic acid .	$C^{10} H^3 O^5$	= 12·875
1 atom ether . .	$C^4 H^5 O$	= 4·625
		17·5

* Ann. de Chim. et de Phys. lxiv. 279.

When a current of pure dry chlorine gas is made to pass over pyromucic ether, it melts, becomes hot, and assumes a yellow colour. Yet nothing is given out but the excess of the chlorine. When the process is at an end, the weight of the ether is about doubled. M. Malagutti has distinguished this new compound by the name of *chloropyromucic ether*.

It is transparent, has the consistence of a syrup, has a strong and agreeable smell of calicanthus, a very bitter taste, and a specific gravity of 1·496. It does not alter vegetable colours. It is not volatile. When we attempt to distil it, much muriatic acid is disengaged, the matter becomes black, thickens, and deposits charcoal, and the liquid that passes over is small in quantity compared with that subjected to distillation. It dissolves readily in alcohol and ether. When exposed to the air it becomes white like milk but recovers its transparency *in vacuo*. Water produces the same effect as the air, but acts more rapidly.

If we pour on it a hot concentrated solution of potash, it becomes instantly coloured, the ether disappears, a white curdy matter separates, while a strong reaction may be perceived. When we add water and raise it to the boiling point, the precipitate disappears. There is a disengagement of alcohol, and in the liquid, which has a very deep colour, we find chlorine but not pyromucic acid.

When ammoniacal gas is passed into an alcoholic solution of this ether, sal ammoniac is formed, and a little hydrocyanate of ammonia, with much charcoal, is deposited, and nothing disengaged but the excess of the ammonia.

From the analysis of this substance by Malagutti, it is evident that it is composed of

4 atoms chlorine . .	Ch^4
1 atom pyromucic acid .	$C^{10}\ H^3\ O^5$
1 atom ether .	$C^4\ H^5\ O$
	$Ch^4\ C^{14}\ H^8\ O^6$

He considers the 4 atoms of chlorine to have combined with the pyromucic acid and to have formed a new acid, to which he has given the name of chloropyromucic acid.

Here then is a new ether formed by the action of chlorine on an ether already existing. Malagutti could not succeed in making a similar compound, when citric, mucic, pyrocitric, pyrotartaric and œnanthic ethers were substituted for pyromucic.

SECTION XIV.—OF SUBERIC ETHER.

This ether was discovered by M. Boussingault, in the year 836.* It may be obtained by heating a mixture of 4 parts alcohol, 1 part muriatic acid, and 2 parts suberic acid. It is somewhat heavier than water; its smell is weak, and its taste disagreeable. It begins to boil at 446°. It is colourless, has an oily

* Ann. der Pharm. xix. 308.

consistency, and is composed, according to Boussingault's analysis, of

Carbon	62·7 or 12 atoms	= 9	or per cent.	62·61
Hydrogen	9·6 or 11 atoms	= 1·375	— —	9·56
Oxygen	27·7 or 4 atoms	= 4·0	— —	27·83
	100·0	14·375		100·00

These numbers may be resolved into

1 atom suberic acid .	$C^8\ H^6\ O^3$
1 atom ether . . .	$C^4\ H^5\ O$
	$C^{12}\ H^{11}\ O^4$

Showing the constitution of the ether.

SECTION XV.—OF ŒNANTHIC ETHER.

This remarkable ether was first examined by Liebig and Pelouze. It is to it that the peculiar odour which distinguishes wines is owing.*

When large quantities of wine are distilled, we obtain at the end of the process a small quantity of an oily liquid. The same liquid is obtained when we distil the lees of wine, especially what is deposited at the bottom of the cask after the fermentation has begun. Liebig and Pelouze got from M. Deleschamps the produce of the distillation of 22000 lbs. of wine (about 2200 imperial gallons), which amounted to $2\frac{1}{3}$th lbs. of this oily liquid.

It has a strong taste, and is generally colourless, though sometimes it has a tinge of green, owing to the presence of a little oxide of copper. This oily liquid is a mixture of œnanthic ether with an excess of œnanthic acid. As the ether is more volatile than the acid, it may be obtained by distillation, retaining only the first portion that comes over. But the best way is to agitate the oily liquid with a solution of carbonate of soda, which dissolves the free acid without altering the ether. The mixture is milky, and does not become transparent by repose. But if we boil it for a few minutes the ether separates and swims on the surface. When it is collected and agitated with fragments of chloride of calcium it is deprived of water.

It is very liquid, and similar in appearance to the volatile oil of mustard. It has a very strong odour of wine, and produces intoxicating effects when inspired. Its taste is strong and disagreeable. It dissolves readily in ether and alcohol, even when the last is dilute. Water does not sensibly dissolve it. Its specific gravity is 0·862. When distilled alone with water not more than $\frac{1}{490}$th part passes over with that liquid. It boils between 437° and 446°.

It was analyzed by Liebig and Pelouze, who obtained

Carbon	71·06 or 18 atoms	= 13·5	or per cent.	72
Hydrogen	11·56 or 18 atoms	= 2·25	— —	12
Oxygen	17·38 or 3 atoms	= 3	— —	16
	100·00	18·75		100

* Ann. de Chim. et de Phys. lxiii. 113.

They found the specific gravity of the vapour of this ether 10·508. Now,

18 volumes carbon weigh	.	7·5
18 volumes hydrogen —	.	1·25
$1\frac{1}{2}$ volume oxygen weighs	.	1·6666
		10·4166

This ether is obviously a compound of

1 atom œnanthic acid	.	C^{14} H^{13} O^2
1 atom ether	. .	C^4 H^5 O
		C^{18} H^{18} O^3

SECTION XVI.—OF CHLOROCARBONIC ETHER.

M. Dumas* filled a glass globe with 915 cubic inches of chlorocarbonic acid gas, and poured into it 464 grains of anhydrous alcohol. The alcohol almost immediately became hot, and assumed an amber colour. The vessel was agitated, and when the action appeared at an end, air was allowed to enter to replace the gas absorbed. In about a quarter of an hour the liquid was taken out of the vessel, and mixed with its own volume of distilled water. Two layers were immediately formed, the heaviest had an oily aspect, and resembled oxalic ether. The ether was watery, and contained a good deal of chlorocarbonic acid. The oily liquid being distilled by the water-bath from chloride of calcium and litharge, exhibited all the characters of an ether.

It forms a colourless liquid, not acting upon litmus paper. It boils at 201°. Its specific gravity is 1·133, at the temperature of 59°. It burns with a green-coloured flame. Its odour is agreeable when air, containing only a little of it, is breathed, but when its vapour is abundant it is suffocating, and occasions intense coughing and tears. The specific gravity of its vapour was found to be 3·82. When placed in contact with hot water it renders it strongly acid.

Concentrated sulphuric acid dissolves it. The solution, especially when heated, gives out abundant vapours of muriatic acid. If we continue the heat the acid blackens, and gives out an inflammable gas.

M. Dumas analyzed this ether, and found it composed of

Carbon	34·2 or 6 atoms	= 4·5	or per cent.	33·03
Hydrogen	5·0 or 5 atoms	= 0·625	— —	4·59
Chlorine	30·7 or 1 atom	= 4·5	— —	33·02
Oxygen	30·1 or 4 atoms	= 4·0	— —	29·36
	100·0	13·625		100·00

This is resolvable into C^2 Ch O^3 + C^4 H^5 O; that is to say, an atom of an acid, composed of

* Ann. de Chim. et de Phys. liv. 226.

2 atoms carbon . . .	= 1·5
1 atom chlorine . . .	= 4·5
3 atoms oxygen . . .	= 3·0
	9·0

Constituting a new acid, the same as oxalic acid united to an atom of chlorine.

$C^4 H^5 O$ is sulphuric ether. It is, therefore, a compound of 1 atom ether, and 1 atom of a new acid not yet observed in a separate state, and not yet distinguished by a name.

The specific gravity of the vapour of this ether corresponds with its analysis. For the specific gravity of

6 volumes carbon vapour .	= 2·5
5 volumes hydrogen . .	= 0·3472
1 volume chlorine . .	= 2·5000
2 volumes oxygen . .	= 2·2222
	2)7·5694
	3·7847

We see that the 14 volumes of atoms constituting this vapour are condensed into 2 volumes.

SECTION XVII.—OF CYANIC ETHER.

This remarkable ether was discovered by Liebig and Wöhler, about the year 1830.* They obtained it by passing liquid cyanic acid into alcohol. The acid was rapidly absorbed. The alcohol became hot and began to boil, but no permanent gas was evolved. There was gradually deposited a considerable quantity of a white crystalline powder. This substance was cyanic ether.

Cyanic ether has neither taste nor smell, nor does it produce any alteration on litmus paper. It is scarcely soluble in cold water. It is even difficult to moisten the crystals with water, they resist the action of that liquid as tallow does. It is more soluble in hot water, but the greater part precipitates again when the solution cools. It dissolves readily in hot alcohol, and is deposited as the liquid cools in regular prismatic crystals. It is soluble also in boiling ether, but not so much so. It appears to dissolve in boiling nitric and sulphuric acids without decomposition.

When heated it melts into a clear liquid, which again concretes into crystals when allowed to cool. When thus melted, a portion is driven off in a vapour, destitute of smell. This vapour is deposited in light-white flocks, like those of oxide of zinc, which fly off when that metal is burnt in the open air. This vapour catches fire at a candle, and burns like cyanogen gas.

When heated in a retort it partly sublimes unaltered, and is partly decomposed. When raised to a temperature at which concentrated

* Poggendorf's Annalen, xx. 395.

sulphuric acid smokes, it boils violently, and a liquid passes over, which is alcohol. What remains in the retort is solid cyanuric acid, which may be dissolved in distilled water, and crystallized.

It was analyzed by Liebig, and found composed of

Cyanogen	50·7645
Carbon	17·8530
Hydrogen	6·0420
Oxygen	25·3405
	100·0000

These numbers give the formula

2 atoms cyanic acid	= 8·5	or per cent.	51·52
4 atoms carbon	= 3	— —	18·18
8 atoms hydrogen	= 1	— —	6·06
4 atoms oxygen	= 4	— —	24·24
	16·5		100

These atomic quantities may be arranged as follows:—

2 atoms cyanic acid	2(C² Az O)	= C⁴ Az² O²
1 atom ether . . .		C⁴ H⁵ O
3 atoms water	3(H O)	H³ O³

Making altogether $\frac{1}{2}$(C² Az O) + C⁴ H⁵ O + 3(H O). The atomic weight of which is 16·5, as in the formula.

SECTION XVIII.—OF CHLOROCYANIC ETHER.

This ether was discovered by M. Aimé, in the year 1837.* It may be obtained by passing a current of chlorine through absolute alcohol, holding cyanodide of mercury in solution, and collecting the product of the distillation. What passes over is a mixture of alcohol and an ethereal liquor. The alcohol may be separated by water. The ether remaining is an oily-looking liquid, having a specific gravity of 1·12. It boils at 122°. It burns with a purple flame, and the vapour produced precipitates nitrate of silver. Alcohol and ether dissolve it. Water throws it down from its alcoholic solution. Liquid ammonia decomposes it instantly with the disengagement of gas.

The alcoholic solution undergoes spontaneous decomposition in 24 hours; and there remains a crystalline substance, which dissolves very well in water.

When heated with water it is easily decomposed. Its smell is similar to that of chloride of cyanogen. It irritates the eyes. Its taste is very similar to that of hydrocyanic acid.

Its constituents, according to Aimé, are

1 atom chloride of cyanogen	C² Az Ch
1 atom ether . . .	C⁴ H⁵ O

It seems to follow, from this compound, that the chloride of cyanogen is an acid, since it combines with and neutralizes ether.

* Ann. de Chim. et de Phys. lxiv. 220.

Iodine and bromine, when substituted for chlorine, do not give similar compounds.

SECTION XIX.—OF ELAIDIC ETHER.

This ether was formed by M. Laurent, in 1837,* by the following process:—He put into a retort 2 parts of elaidic acid, 1 part of sulphuric acid, and 4 parts of alcohol. The mixture was kept boiling for several hours, taking care to pour back into the retort every thing that had passed into the receiver. When the boiling was finished he washed the stratum of oil which had remained in the retort with hot water. It was then repeatedly agitated with a weak and hot solution of caustic potash, to remove a little uncombined elaidic acid. As the ether had a yellow colour, it was purified by distilling it off dry chloride of calcium.

Elaidic ether thus prepared is liquid, and colourless. It has a slight odour of distilled tallow, which it loses when boiled in water. Its specific gravity is 0·868. It is insoluble in water. Alcohol dissolves about the eighth part of its weight, while ether dissolves it in every proportion. It boils when heated a little above 698°, and it may be distilled over unaltered. It is not acted on by potash dissolved in water, but it is decomposed when boiled with an alcoholic solution of potash. It is soluble in concentrated sulphuric acid. When heated on platinum foil, it burns like common oils.

Its constituents, as determined by the analysis of Laurent, are

Carbon	76·01	or 39 atoms =	29·25	or per cent.	76·97
Hydrogen	12·36	or 38 atoms =	4·75	— —	12·50
Oxygen	11·63	or 4 atoms =	4·00	— —	10·53
	100·00		38		100·00

These atoms may be resolved into $C^4\ H^5\ O + C^{35}\ H^{33}\ O^3$; or an atom of ether combined with an atom of elaidic acid. It follows from this analysis, that an atom of elaidic acid is $C^{35}\ H^{33}\ O^3$, and consequently that its atomic weight is 33·375.

By a similar process, Laurent prepared margaric ether and oleic ether. The specific gravity of this last ether is 0·871.

IV. The fourth set of bodies, which have by some been classed among *ethers*, are certain acidulous salts, consisting of 1 atom of ether united to 2 atoms of an acid. They may be considered as the ethers of the last set, united each to an additional atom of the acid, which is combined with and neutralizes the ether. The following are the principal salts of this kind hitherto examined:—

1 Heavy oil of wine $C^4\ H^4\ (H^4\ O^4) + S\ O^3$
2 Althionic acid . $C^4\ H^5\ O + 2\ (S\ O^3) + H\ O$
3 Phosphovinic acid $C^4\ H^5\ O + 2\ (Ph\ O^{2\frac{1}{2}})$
4 Oxalovinic acid $C^4\ H^5\ O + 2\ (C^2\ O^3) + H\ O$
5 Tartrovinic acid $C^4\ H^5\ O + 2\ (C^4\ H^2\ O^5) + H\ O$

* Ann. de Chim. et de Phys. lxv. 298.

6 Racemovinic acid $C^4 H^5 O + 2 (C^4 H^2 O^5) + H O$
7 Camphovinic acid $C^4 H^5 O + 2 (C^{10} H^{7\frac{1}{2}} O^5) + H O$

These salts have, in compliance with the opinions entertained by the original discoverers of them, been described in the first part of this volume, while treating of compound acids. In reality, their true place is immediately after the acid ethers, of which they constitute a kind of complement.

CHAPTER III.

OF PYROXYLIC SPIRIT AND ITS COMPOUNDS.

Dumas informs us that this remarkable substance was discovered by Mr Philip Taylor, in 1812, but that he did not make it known to the public till 1822, in a letter to the editors of the *Philosophical Journal*.* Never having seen this communication of Mr Philip Taylor, I do not know the evidence which he has brought forward in proof of his being the discoverer. But I have been myself in the habit of using it in lamps ever since 1816. And when I went to Glasgow, in 1817, I found that it was prepared for sale in that city, by Messrs Turnbull and Ramsay. It was, undoubtedly, therefore, well known in this country long before 1822, the date of Mr Taylor's communication.

When wood is distilled for the purpose of obtaining acetic acid, the pyroxylic spirit is formed, and found in the aqueous liquid which comes over. It is decanted off to separate it from the tar which comes over at the same time. This aqueous liquid being subjected again to distillation, it is in the first tenth part of the product that we are to look for the pyroxylic spirit. By repeated rectifications it is obtained in a state of considerable purity. The last rectifications must be made over quick lime, partly to remove water, and partly some other impurities. The quantity of ammonia disengaged, when the lime is added, is considerable. This ammonia was in combination with acetic acid.

Pyroxylic spirit is pure when it does not become coloured by exposure to the air and light, when it mixes with water in all proportions without becoming muddy, and when it does not form a black precipitate when mixed with protonitrate of mercury, and has no action on paper stained with vegetable colours. The quantity of it contained in the liquid obtained by distilling wood, is about 1 per cent.

Mr Kane, of Dublin, published an interesting set of experiments on pyroxylic spirit, in 1836.† He informs us that he had begun the examination of it before the appearance of Dumas' paper; and I remember hearing a paper on the subject read by him, at the meeting of the British Scientific Association at Dublin, in 1835.

* Chimie Appliquée aux Arts, v. 422. † Ann. der Pharmacie, xix. 164.

He purified the spirit by saturating it with dry chloride of calcium. The saturated solution crystallizes in long shining six-sided tables. He distilled these crystals over the water-bath, as long as they yielded spirit, and then adding water, continued the distillation.

It is colourless, very fluid, and has a peculiar smell, at once alcoholic and aromatic, and mixed with the odour of acetic ether.

It boils by my trials at 150°. Dumas and Peligot state the boiling point to be 151°·7,* under a pressure of 29·96 inches of mercury; Macair and Marcet, 150°;† while Leopold Gmelin makes it as low as 137°;‡ and Kane found it 140°.§

The tension of its vapour at 570° is 3·27 inches of mercury. The specific gravity of the liquid at 68° is 0·798. So that in this respect it does not differ much from alcohol. The specific gravity of its vapour at the temperature of boiling water is 1·120, that of air being unity.

It was analyzed by MM. Dumas and Peligot, and by Mr Kane, of Dublin, who obtained

	D. & P.	Kane.			
Carbon	37·22	37·15	1 atom	= 0·75	or per cent. 37·5
Hydrogen	12·46	12·39	2 atoms	= 0·25	— — 12·5
Oxygen	50·32	50·46	1 atom	= 1·00	— — 50·0
	100·00	100‖		2·00	100

We might consider it as a compound of 1 atom carbo-hydrogen, and 1 atom water. But the analogy of ether renders it more likely that it is an oxide of dicarburetted hydrogen.

Dumas and Peligot found the specific gravity of the vapour of pyroxylic spirit to be 1·120, while Kane obtained 1·121, or almost exactly the same result.

Now, 1 volume carbon vapour weighs .	0·4166
2 volumes hydrogen gas weigh .	0·1388
½ volume oxygen gas weighs . .	0·5555
	1·1111

Hence, it is obvious that the vapour consists of 1 volume carbon, 2 volumes hydrogen, and half a volume oxygen, condensed into 1 volume.

Pyroxylic spirit may be preserved without alteration in a vessel, though imperfectly corked. But when its vapour mixed with air

* Ann. de Chim. et de Phys. lviii. 10. † Bibliotheque Universelle, xxiv. 126.
‡ Handbuch der Theoret. Chimie, ii. 344. § Ann. der Pharmacie, xix. 165.
‖ Liebig obtained Carbon . . . . 54·20
Hydrogen . . . 11·11
Oxygen . . . 34·69
100
But the specific gravity was 0·804. The substance analyzed was different from pyroxylic spirit. Liebig got it from L. Gmelin. Ann. der Pharm. v. 32.

is left in contact with spongy platinum, much heat is evolved, and formic acid is formed.

To make this experiment with ease, let a glass cylindrical jar, open at both ends, be placed upon a large plate containing distilled water. Put 3 or 4 capsules, containing from 200 to 300 grains of spongy platinum within the jar, and also some pyroxylic spirit in a wine glass, and within the glass jar. By degrees the vapour of the pyroxylic spirit diffuses itself through the glass jar, and the reaction commences whenever a mixture of this vapour and air comes in contact with the spongy platinum. Abundance of vapours condense on the sides of the glass, which trickle down into the water, and gives it an acid taste. If the pyroxylic spirit be renewed in proportion as it evaporates, the liquid in a few days contains enough of acid to enable us to ascertain that it is impregnated with *formic acid*. When alcohol is treated in the same way, *acetic acid* is formed.

What happens in this case will be understood by inspecting the following formulæ :—

2 atoms of pyroxylic spirit are $C^2\ H^4\ O^2$
1 atom of formic acid . $C^2\ H\ O^3$

Hence, to convert 2 atoms of pyroxylic spirit into 1 atom of formic acid, we must abstract 3 atoms of hydrogen, and add 1 atom of oxygen. The oxygen of the atmosphere, by the intervention of the spongy platinum, converts 3 atoms of hydrogen into water, and adds 1 atom of oxygen.

If we let the pyroxylic spirit fall, drop by drop, on the spongy platinum, it becomes incandescent, and the spirit burns, producing carbonic acid in great quantity.

Chlorine acts upon pyroxylic spirit much less violently than upon alcohol. When it is poured into a phial of dry chlorine gas, hardly any heat is evolved, and the action is slow, even when assisted by the solar influence. Even when chlorine and pyroxylic spirit are agitated together, the action is very slow. It is necessary to distil the liquid a number of times in contact with chlorine. Two liquids are produced very different in their volatility. The least volatile combines with ammonia, and forms a crystallizable compound.

But Mr Kane found, that when dry chlorine gas and vapour of pyroxylic spirit come in contact, an explosion takes place. He passed a current of chlorine through the spirit to saturation. Much muriatic acid was formed. He obtained two liquids. The lightest was very acid. The other was thick, had nearly the specific gravity of sulphuric acid, had a sharp and biting taste, and reddened litmus, doubtless because not quite free from muriatic acid. It was analyzed by Mr Kane, who obtained

Carbon	21·52
Hydrogen	1·56
Oxygen	10·35
Chlorine	66·57
	100·00

From these numbers we might deduce the following formula:—

$2\frac{3}{4}$ atoms carbon	= 2·0625	or	per cent.	20·75
1 atom hydrogen	= 0·1250	—	—	1·25
1 atom oxygen	= 1·0000	—	—	10·10
$1\frac{1}{2}$ atom chlorine	= 6·7500	—	—	67·90
	9·9375			100

But this formula is so unlikely to represent the true constitution of a body, that it would be wrong to adopt it without further investigation.

When pyroxylic spirit is distilled with a solution of chlorite of lime (or bleaching powder) a liquid is obtained, to which Dumas, who investigated its nature, has given the name of *chloroform*. It has been already described in a preceding Chapter.

It was discovered about the same time by MM. Soubeiran* and Liebig,† by distilling a mixture of alcohol and solution of chlorite of lime. But Dumas assures us that its nature is the same, whether we employ alcohol or pyroxylic spirit.‡

Pyroxylic spirit dissolves potash and soda. The solutions are similar to those of alcohol. They become brown-coloured when exposed to the action of the atmosphere.

When pyroxylic spirit, concentrated as much as possible, is brought in contact with barytes, it becomes hot, dissolves the base, and remains combined with it. To obtain the solution pure, we must add barytes in powder to absolute pyroxylic spirit, filter the solution, and evaporate *in vacuo*. A crystalline compound remains, composed of

Barytes . .	70·5 or 1 atom	= 9·5
Pyroxylic spirit	29·5 or 2 atoms	= 4
	100	13·5

When this compound is cautiously distilled, it furnishes a liquid similar to pyroxylic spirit; then melts and yields an oily product. Finally, it blackens slightly, and the barytes is left in the state of a carbonate.

When hot pyroxylic spirit is saturated with barytes, it deposits on cooling, silky needles, which speedily become brown when exposed to the air.

Pyroxylic spirit dissolves salts almost like alcohol. It precipitates the sulphates from aqueous solutions. It dissolves chloride of calcium in abundance, and forms with it a crystallizable compound.

It dissolves the resins, and as it is more volatile than alcohol, it answers exceedingly well for making varnishes. It is not so good a solvent of very hydrogenous bodies as alcohol; but it is an excellent solvent of bodies which contain much oxygen.

When a mixture of 1 part of pyroxylic spirit, and 4 parts of concentrated sulphuric acid is distilled, a gas comes over, which possesses exactly the constitution of alcohol vapour.

* Ann. de Chim. et de Phys. xlviii. 131. † Ibid. xlix. 146. ‡ Ibid. lviii. 15.

It has an ethereal smell, is totally soluble in water, and burns with a flame similar to that of alcohol. At first it is mixed with carbonic acid gas, and sulphurous acid gas; but if it be left for 24 hours in contact with fragments of potash, these impurities are dissolved. The specific gravity of this gas, as determined by MM. Dumas and Peligot, is 1·617.

A volume of it requires for complete combustion 3 volumes of oxygen gas, and forms 2 volumes of carbonic acid. Hence it contains

2 volumes carbon .	0·8333	condensed into
2 volumes hydrogen	0·1388	1 volume.
	0·9722	

If we subtract 0·9722 from 1·617, the specific gravity of the gas, the remainder 0·6248 is almost exactly equal to the specific gravity of a volume of vapour of water, namely, 0·625. Hence it is obvious that this vapour is a compound of

1 volume olefiant gas .	0·9722
1 volume vapour of water	0·625
	1·5972

condensed into 1 volume; which gives precisely the elements that enter into the constitution of alcohol.

The very same thing takes place in this distillation as when we heat a mixture of alcohol and sulphuric acid. One half the water is abstracted relative to the other ingredient, the carbohydrogen. When alcohol is used, the deutocarbohydrogen, or olefiant gas, is converted into ether; but when pyroxylic spirit is used, the compound is $C^2 H^3 O$, or it contains an atom of olefiant gas less than ether. This is the same thing in both cases as abstracting one half of the water which the spirit contained. But in reality

Alcohol is . .	$C^4 H^5 O + H O$
While this gas is .	$C^2 H^2 + H O$

We see the reason why its properties are so different from those of alcohol.

Action of the hydracids on pyroxylic spirit. When pyroxylic spirit is made to act on the hydracids, a set of compounds is formed very analogous to the ethers which the same acids form with alcohol. These bodies have been examined by Dumas and Peligot, who consider them as compounds of the hydracid employed and methylene, which in their opinion acts the part of a base.*

* Dumas and Peligot have given the name of *methylene* to what they consider to be the base of pyroxylic spirit, and which they make $C^2 H^2$, and pyroxylic spirit they make $C^2 H^2 + H O$. But the subject will be much simplified if we apply Liebig's theory of ethers to pyroxylic spirit with the requisite modification. The base of pyroxylic spirit will be $C^2 H^3$, and pyroxylic spirit will be $C^2 H^3 O$. This base has not yet been insulated, but the following salts are obviously the chloride and iodide of $C^2 H^3$, which we may, after Dumas and Peligot, denominate methylene.

It follows from the experiments of Dumas and Peligot, that pyroxylic spirit is

1. *Chloride* or *muriate of methylene.* This compound, analogous to muriatic ether, is most conveniently obtained by heating a mixture of two parts of common salt, one part of pyroxylic spirit, and three parts of concentrated sulphuric acid. By the application of a gentle heat, a gas is obtained, which may be collected over water, and which is pure muriate of methylene.

This gas retains its elasticity though cooled down to zero, or even a degree lower. It is colourless, has an ethereal odour, and a sweet taste. It burns with a flame, white in the middle, and green round the edges. Water dissolves 2·8 times its bulk of it, at the temperature of 61°, and when the barometer stands at 30 inches. It does not alter vegetable blues, nor does it precipitate nitrate of silver. When detonated with an excess of oxygen gas, it is decomposed, and the products are water, carbonic acid, muriatic acid, and some traces of chlorine. The water formed is sufficient to condense the muriatic acid disengaged. Each volume of gas requires $1\frac{1}{2}$ volume of oxygen, and produces a volume of carbonic acid gas. Hence it is obvious that every volume of the gas contains a volume of carbon vapour, and a volume of hydrogen gas, united into a volume of carbohydrogen. The specific gravity of gaseous chloride of methylene is . . . . 1·7310

That of carbohydrogen . . 4861

1·2449

Now, the specific gravity of muriatic acid gas is 1·28472, almost identical with this residue. Hence there can be no doubt that the chloride of methylene is composed of C H^2 Chl.

C H^2 O. Perhaps it would be better to double these numbers, and to consider it as C^2 H^3 O + H O. It would then bear the same relation to the base which these chemists have distinguished by the name of methylene, that alcohol does to ether. On that view we might consider the unknown basis of pyroxylic spirit to be C^2 H^3, or *methyl.* Of this pyroxylic spirit is the hydrated oxide. The other compounds, by Dumas and Peligot's analysis, are

Chloride or muriate of methylene .	C^2 H^4 + Chl^2
Iodide or hydriodate . . .	C^2 H^3 + Iod
Fluoride of fluate	C^2 H^3 + Fl

The salts of methylene, analogous to the acid ethers, are the following:—

Sulphate . . .	C^2 H^3 O + S O^3
Nitrate . . .	C^2 H^3 O + Az O^3
Oxalate . .	C^2 H^3 O + C^2 O^3
Acetate . . .	C^2 H^3 O + C^4 H^3 O^3
Formate . . .	C^2 H^3 O + C^2 H O^3
Benzoate . . .	C^2 H^3 O + C^{14} H^5 O^3
Mucate . . .	C^2 H^3 O + C^6 H^4 O^7
Oxychlorocarbonate .	C^2 H^3 O + C^2 Chl O^3
Chlorocyanate . .	C^2 H^3 O + (C^2 Az) Chl
Cyanate . . .	C^2 H^3 O + 2 (C^2 Az O) + 3 (H O)

The acidulous methylene salts, similar to althionic acid, and the other compound ethereal salts, are the following:—

Sulphomethylic acid .	C^2 H^3 O + 2 (S O^3)
Tartromethylic . .	C^2 H^3 O + 2 (C^4 H^2 O^5)
Racemomethylic . .	C^2 H^3 O + 2 (C^4 H^2 O^5)

It is therefore pyroxylic spirit, with an atom of chlorine substituted for an atom of oxygen.

When this gas is made to pass through a red-hot porcelain tube, it undergoes complete decomposition, being converted into muriatic acid and a carburetted gas, while the porcelain tube is lined with a thin coat of charcoal. The carburetted gas is simple carbohydrogen, for a volume requires for complete combustion 1·5 volume oxygen gas, and forms 1 volume of carbonic acid.

2. *Iodide* or *hydriodate of methylene.* This compound is easily obtained by distilling a mixture of 1 part of phosphorus, 8 parts of iodine, and 15 parts of pyroxylic spirit. The iodine is dissolved in the pyroxylic spirit. The solution is put into a retort, and the phosphorus added by little and little. The first fragments added occasion a lively effervescence, with the evolution of heat, and the production of hydriodic acid. When the ebullition thus produced is at an end, the rest of the phosphorus is added, and the whole agitated. By and by heat must be applied, otherwise the effervescence would cease altogether. The distillation is continued as long as an ethereal liquid continues to pass.

The residue in the retort contains phosphorous acid, phosphomethylic acid, and phosphorus. It is quite deprived of colour. The liquid in the receiver is composed of pyroxylic acid and iodide of methylene. When water is added to the mixture the iodide immediately separates. The quantity obtained nearly equals the weight of the iodine employed. It is still very impure. To obtain it in a state of purity, we must distil it over the water-bath with chloride of calcium, and litharge in great excess.

It is a colourless liquid, weakly combustible, burning only when put into the flame of a lamp, and then giving out violet vapours in great abundance. Its specific gravity at 71° is 2·237. It boils when heated to between 100° and 120°.

Dumas and Peligot analyzed it by means of oxide of copper, and obtained

Carbon	8·92 or 2 atoms	= 1·5	or per cent.	8·51
Hydrogen	2·23 or 3 atoms	= 0·375	— —	2·12
Iodine	88·85 or 1 atom	= 15·75	— —	89·37
	100·00	17·625		100

or C^2 H^3 Iod.

Dumas and Peligot found the specific gravity of the vapour of iodide of methylene 4·883. This specific gravity would indicate

1 volume carbon . . .	0·4166
2 volumes hydrogen . .	0·1388
1 volume iodine vapour .	8·8000
	2)9·3555
	4·6777

condensed into 2 volumes. It is obvious that there is an error either

in determining the composition of the iodide, or in that of the specific gravity of the vapour.

3. *Fluoride* or *Fluate of methylene.* This compound was obtained by Dumas and Peligot* in the following manner :—

A mixture of fluet of potassium and sulphate of methylene was gently heated in a glass vessel. Sulphate of potash was formed, and a gas escaped, which being collected over water, was pure, and constituted fluate of methylene.

It is colourless, has an ethereal smell, and burns with a flame, similar to that of alcohol, only a little more mixed with blue. During its combustion, fluoric acid is developed, and appears in white fumes.

It is but little soluble in water, 100 of water at 60°, absorbing 166 volumes of the gas. Its specific gravity was 1·186. It was composed of

1 volume methylene
1 volume fluoric acid

united together, and condensed into 1 volume ; or it is composed of

1 atom fluoric acid . . .	1·25
1 atom methylene . . .	1·875
	3·125

So that its atomic weight is 3·125.

Action of the oxacids on pyroxylic spirit. When the oxacids are made to act upon pyroxylic spirit, two different compounds are formed ; one corresponding with the ethers formed by means of the same acids and alcohol, and which are in reality neutral salts ; another constituting acid salts, and corresponding with althionic and other similar acids.

The former, which are perfectly neutral, are obtained more easily than the corresponding alcohol ethers. They all contain an atom of $C^2 H^3 O$, united to an atom of the acid. They are more volatile, and more stable than the corresponding alcoholic compounds.

1. *Sulphate of methylene.* No compound made from alcohol corresponding to this is known. The simplest method of obtaining it is to distil one part of pyroxylic spirit with eight or ten parts of concentrated sulphuric acid. As soon as ebullition commences there passes into the receiver an oily liquid, mixed with a methylic liquor. This oily liquid becomes gradually very abundant, and when the distillation is finished, its quantity is at least equal to that of the pyroxylic spirit employed. The acid mixture should be distilled slowly, but the boiling should be constantly kept up.

This oily liquid being separated by decantation from the aqueous liquor, is first agitated with a little water, and then with a little chloride of calcium. It is then rectified several times successively over caustic barytes in a very fine powder. Finally it is proper to leave it for some time in the vacuum of an air pump with concentrated sulphuric acid and potash. The object of these processes is to

* Ann. de Chim. et de Phys. lxi. 193.

separate some sulphuric acid, sulphurous acid, water, and pyroxylic spirit, which the liquid may contain.

When pure it is colourless, has an alliacious smell, and a specific gravity of 1·324 at the temperature of 71°½. It boils at the temperature of 370°, under a pressure of thirty inches of mercury.

Dumas and Peligot subjected it to analysis by means of oxide of copper, and found 100 parts of it to yield

Carbon	19·03
Hydrogen	4·78

Now, these two numbers are to each other in the proportion of

2 atoms carbon . . .	= 1·5
3 atoms hydrogen . . .	= 0·375

If we consider it as composed of

2 atoms carbon	= 1·5	or per cent.	19·04
3 atoms hydrogen	= 0·375	— —	4·76
1 atom oxygen	= 1·000	— —	12·70
1 atom sulphuric acid	= 5·000	— —	63·50
	7·875		100·00

Then it consists obviously of

$$C^2\ H^3\ O + S\ O^3$$

If $C^2\ H^3\ O$ be methylene, it is a sulphate of methylene.

Dumas and Peligot attempted to determine the density of the vapour of sulphate of methylene. They obtained as a result 4·565. But they do not consider this number as deserving of confidence. There can be little doubt that the true specific gravity of the vapour of this substance is 4·3750, for it obviously consists of

1 volume methylene vapour .	1·5972
1 volume sulphuric acid . .	2·7777
	4·3750

The sulphate of methylene may not only be distilled over without alteration, but it may be heated to 392° without undergoing any decomposition. It is slowly decomposed by cold water, and rapidly by boiling water. The last acts with violence, evolving much heat, and the sulphate disappears altogether, without producing any new oil. Sulphomethylic acid is formed, and pyroxylic spirit is regenerated.

Caustic barytes has no action on it. Hydrate of barytes, and the hydrated alkalies, or their aqueous solutions, decompose it with great facility. Thus, solution of potash converts it, with much heat, into sulphomethylate of potash and pyroxylic spirit.

By means of sulphate of methylene all the other compounds of methylene and acids may be obtained. Thus, when heated with fused common salt, sulphate of potash is formed, and muriate of methylene is disengaged in the gaseous form. When heated with fluoride of potassium, hydrofluate of methylene is disengaged in the gaseous state. When heated with cyanodide of mercury, or of potassium, sulphate of potash, or sulphate of mercury is formed, and cyanodide of methylene may be collected in the liquid form.

When it is distilled with benzoate of potash, we obtain benzoate of methylene; and so on.

When 2 parts of pyroxylic spirit, 2 parts of binoxide of manganese, and 3 parts of sulphuric acid, diluted with their own weight of water, are mixed, a violent effervescence takes place, and a great deal of formic acid is evolved. The other products from the distillation of this mixture have been examined with great care by Mr Kane.*

2. *Nitrate of methylene.* This compound was obtained by Dumas and Peligot by putting into a retort 50 parts of nitre, 100 parts of sulphuric acid, and 50 parts of pyroxylic spirit. The retort should be large, and connected with a large receiver communicating with a bottle containing salt water, and surrounded with a refrigerating mixture, and from this should pass a tube capable of conducting the gas formed into the chimney. It is only necessary to apply heat at the commencement of the process. Afterwards it goes on of its own accord. When the process is finished, the liquid in the receiver is poured into the bottle. In this way we obtain at the bottom of the bottle a colourless layer of the new compound. It must be separated by decantation and purified by distilling it off a mixture of massicot and chloride of calcium.

Thus prepared it is impure. If it be heated to the temperature of 140°, it boils and gives off a substance having a decided odour of hydrocyanic acid. The temperature gradually rises to 151°. What comes over at that temperature is considered by Dumas and Peligot to be in as pure a state as they could procure it.

It is a colourless liquid, having a specific gravity of 1·182 at the temperature of 71°. It boils at 151°, giving out a weak ethereal odour. It is perfectly neutral, and burns with a lively yellow flame. When the vapour is heated to about 302°, it detonates with great violence, so as to produce dangerous results if the quantity be considerable.

Dumas and Peligot analyzed it by means of oxide of copper. The result of 5 analyses made in this way led to the conclusion that it was composed of

2 atoms carbon . . .	= 1·5
3 atoms hydrogen . . .	= 0·375
1 atom azote . . .	= 1·75
6 atoms oxygen . . .	= 6·00
	9·625

This is equivalent to $C^2\ H^3\ O + N\ O^5$.

They found the specific gravity of the vapour of nitrate of methylene to be 2·640. Now,

1 volume methylene . .	= 1·5972
1 volume nitric acid vapour .	= 3·7500
	2)5·3472
	2·6736

* Annalen der Pharmacie, xix. 175.

This result agrees as nearly as could be expected with the specific gravity of the vapour found.

When pyroxylic spirit is treated with nitric acid and silver, in the well known method for obtaining detonating silver, no violent action takes place. Nitrate of methylene distils over; and towards the end of the process, if the nitric acid was strong, oxalate of silver is deposited.* The same thing happens when we substitute mercury for silver.

3. *Oxalate of methylene.* The method of obtaining this compound, is to distil a mixture of equal parts sulphuric acid, oxalic acid, and pyroxylic spirit. There passes over into the receiver a spirituous liquor which, when exposed to the air, speedily evaporates, leaving a residue crystallized in fine rhomboid plates. As the distillation proceeds, the quantity of this crystalline matter increases. At last the whole liquors that pass over assume a solid consistency. When the distillation is terminated, if we allow the retort to cool, and add as much pyroxylic spirit as at first, and distil a second time, we obtain the same product.

The crystals from these two distillations being well drained on a filter, are to be melted over an oil-bath to dry them, and distilled over massicot to free them from oxalic acid. The product thus obtained is pure oxalate of methylene.

It is colourless, and has a smell similar to oxalic ether. It melts at 124°, and boils at 322°, under a pressure of 30 inches of mercury. It dissolves in cold water, and speedily undergoes decomposition when thus dissolved, especially if it be heated, being converted into oxalic acid and pyroxylic spirit.

It is soluble in alcohol and pyroxylic spirit, and more soluble when these liquids are hot than when cold. The alkaline hydrates destroy it rapidly, forming oxalates and pyroxylic spirit. But anhydrous bases, or at least oxide of lead, do not alter it; anhydrous ammonia converts it into a new substance. Liquid ammonia converts it into oxamide.

Dumas and Peligot analyzed it by means of oxide of copper, and obtained for its constituents

Carbon	41·08
Hydrogen	5·28
Oxygen	53·64
	100·00

These numbers approach

4 atoms carbon	= 3	or per cent.	40·68
3 atoms hydrogen	= 0·375	— —	5·08
4 atoms oxygen	= 4	— —	54·24
	7·375		100·00

This is equivalent to $C^2\ H^3\ O + C^2\ O^3$.

4. *Acetate of methylene.* This compound may be obtained in

* Dumas and Peligot, Ann. de Chim. et de Phys. xi. 195.

abundance by distilling a mixture of 2 parts pyroxylic spirit, 1 part crystallizable acetic acid, and 1 part sulphuric acid of commerce. The product obtained is put in contact with a solution of chloride of calcium, which separates an abundant ethereal liquid, containing much acetate of methylene. As it still contains some sulphurous acid, and some pyroxylic spirit, it is agitated with quick lime, and then left to digest over chloride of calcium for 24 hours, which absorbs the pyroxylic spirit. It is a colourless ethereal liquid, having an agreeable odour, analogous to that of acetic ether. It boils at 136°½ under a pressure of 30 inches of mercury. Its specific gravity is 0·919 at the temperature of 71°½. Its constituents, determined by the analysis of Dumas and Peligot, are

Carbon	49·2 or 6 atoms	= 4·5	or per cent.	48·65
Hydrogen	8·3 or 6 atoms	= 0·75	— —	8·11
Oxygen	42·5 or 4 atoms	= 4·00	— —	43·24
	100·0	9·25		100·00

This is equivalent to $C^2 H^3 O + C^4 H^3 O^3$.

The specific gravity of the vapour of acetate of methylene is 2·563, as determined by Dumas and Peligot. Now, the specific gravity of

1 volume methylene vapour .	= 1·5972
1 volume acetic acid vapour .	= 3·5416
	2) 5·1388
	2·5694

M. Laurent passed a current of chlorine gas slowly through acetate of methylene, and then distilled the liquid, leaving out the first portions which contained two oils. He obtained a colourless liquid, heavier than water, insoluble in water, but soluble in ether and alcohol. It boiled at 293°, and could be distilled over unaltered. Liquid potash attacked it, the liquid became brown, and a vapour was disengaged having a strong smell and a sweet taste. Perhaps, also, formate of potash was formed. The liquid was analyzed by Laurent, and found composed of

Carbon	20·25
Hydrogen	1·71
Chlorine	63·09
Oxygen	14·95
	100·00

From these numbers (which are only distant approximations) he deduces the following formula:—

6 atoms carbon	= 4·5	or per cent.	22·09
3 atoms hydrogen	= 0·375	— —	1·84
3 atoms chlorine	= 13·5	— —	66·25
2 atoms oxygen	= 2·0	— —	9·82
	20·375		

But it would be unsafe to draw deductions from this analysis.*

* Ann. de Chim. et de Phys. lxiii. 382.

5. *Formate of methylene.* Dumas and Peligot obtained this compound by distilling in a retort a mixture of about equal parts of sulphate of methylene and dry formate of soda. When the mixture is gently heated, the reaction commences, and the temperature becomes speedily high enough, to allow the process to go on without the farther application of artificial heat. A very volatile liquid passes into the receiver, which must be kept cool. This liquid is formate of methylene nearly in a state of purity.

To make it quite pure, it should be distilled first over a fresh quantity of formate of soda, and afterward alone in a dry retort over a water-bath.

Pure formate of methylene thus obtained is very volatile, lighter than water and has an agreeable ethereal smell. It was analyzed by Dumas and Peligot by means of oxide of copper, and found to be composed of

Carbon	40·66	or 4 atoms	= 3	or per cent.	40
Hydrogen	6·83	or 4 atoms	= 0·5	— —	6·7
Oxygen	52·50	or 4 atoms	= 4	— —	53·3
	100·00		7·5		100·0

Equivalent to $C^2\ H^3\ O + C^2\ H\ O^3$

The specific gravity of vapour of formate of methylene, as determined by Dumas and Peligot, is 2·084. Now

1 volume methylene vapour .	= 1·5772
1 volume vapour of formic acid .	= 2·5672
	2)4·1644
	2·0822*

6. *Benzoate of methylene.* This compound may be obtained by distilling a mixture of 2 parts of benzoic acid, 2 parts of sulphuric acid, and 1 part of pyroxylic spirit, and mixing the liquid which passes over into the receiver with water. The ethereal portion separates. After washing it two or three times with water, let it be agitated with chloride of calcium, decanted off, and distilled over dry massicot. Finally, let it be boiled till its point of ebullition becomes fixed. It ought to be 388°½.

Benzoate of methylene is oily, colourless, and has an agreeable balsamic odour. Its specific gravity is 1·10 at 62°½. It is insoluble in water, but it dissolves readily in pyroxylic spirit, alcohol, and ether.

Its constituents, determined by the analysis of Dumas and Peligot, are

Carbon	71·4	or 16 atoms	= 12	or per cent.	70·59
Hydrogen	6·2	or 8 atoms	= 1	— —	5·88
Oxygen	22·4	or 4 atoms	= 4	— —	23·53
	100·0		17		100·00

Now these atomic numbers may be grouped as follows:—

* Ann. de Chim. et de Phys. lxiii. 48.

1 atom methylene	.	$= C^2\ H^3\ O$
1 atom benzoic acid	.	$= C^{14}\ H^5\ O^3$
		$C^{16}\ H^8\ O^4$

Thus its constitution is precisely similar to that of the other salts of methylene which have been already described.

Dumas and Peligot found that benzoate of methylene may be obtained by distilling a mixture of dry benzoate of soda and neutral sulphate of methylene.

The specific gravity of the vapour of benzoate of methylene, as determined by Dumas and Peligot, is 4·717. Now

1 volume methylene gas	.	= 1·5772
1 volume benzoic acid vapour		= 7·8475
		2)9·4247
		4·7123

7. *Mucate of methylene.* This compound was first formed in 1836, by M. Malagutti.* The process for preparing it is precisely the same as that for preparing mucic ether, only substituting pyroxylic spirit for alcohol.

It is solid, crystallized, colourless, fixed, and insipid. It may be obtained in crystals, either from alcohol or water, but the crystals are not so distinctly shaped as those of mucic ether. When viewedwith a microscope they appear to be rectangular prisms with bevelled summits.

When heated the mucate of methylene undergoes decomposition before it melts. Decomposition begins at the temperature of 325°½ and shows itself by the evolution of a black oily matter; at 345°·2 it assumes the form of a black liquid, which swells and gives out carburetted hydrogen.

It is very little soluble in boiling alcohol, one part requiring 200 of alcohol of 0·814 to dissolve it. When the solution cools the mucate almost all falls under the form of a crystalline powder. It is very soluble in boiling water; but partly precipitates as the solution cools. The specific gravity of the crystals from alcohol is 1·48, that of those from water 1·53.

M. Malagutti analyzed this mucate of methylene, and obtained

Carbon	40·16 or 8 atoms	= 6	or per cent.	40·34
Hydrogen	5·91 or 7 atoms	= 0·875	— —	5·88
Oxygen	53·93 or 8 atoms	= 8·0	— —	53·78
	100·00†	14·875		100·00

Equivalent to $C^2\ H^3\ O + C^6\ H^4\ O^7$. Thus it agrees in its compositions with all the preceding compounds.

8. *Oxy-chloro-carbonate of methylene.* When pyroxylic spirit is introduced to a glass vessel filled with chloro-carbonic acid the temperature rises suddenly, and the reaction is terminated in a very short time. Muriatic acid is formed, and chloro-carbonate of

* Ann. de Chim. et de Phys. lxiii. 94. †Ibid. p. 295.

methylene, which separates under the form of a heavy oil when the pyroxylic spirit employed contains some water. It is easily separated from the water by decantation. It must then be rectified by distilling it by the vapour-bath over a great excess of chloride of calcium and massicot. Should it be suspected of still retaining any pyroxylic spirit, it may be digested without heat over fragments of chloride of calcium.

Thus purified it is a colourless liquid, very fluid, has a penetrating odour, is very volatile, and heavier than water. It burns with a green flame.

From the analysis of Dumas and Peligot, it follows that the constituents of this chloro-carbonate are

Carbon	25·57 or 4 atoms	= 3	or per cent.	25·26
Hydrogen	3·46 or 3 atoms	= 0·375	— —	3·16
Chlorine	37·12 or 1 atom	= 4·5	— —	37·90
Oxygen	33·85 or 4 atoms	= 4·0	— —	33·68
	100·00	11·875		100·00

Equivalent to $C^2\ H^3\ O + (C^2\ O^3)\ Chl$

An atom of the water which enters into the constitution of pyroxylic spirit is decomposed, its hydrogen uniting to the chlorine of the chloro-carbonic acid, and converting it into muriatic acid, while the oxygen takes the place of that chlorine; so that 2 atoms of chloro-carbonic acid, $C^2\ O^2\ Chl^2$, become $C^2\ O^3\ Chl$, or an atom of oxychloro-carbonic acid.*

9. *Chlorocyanate of methylene.* This compound was discovered in 1837 by M. Aimé, who obtained it by passing a current of chlorine through a solution of cyanodide of mercury in pyroxylic spirit,† and washing the liquid that distilled over in water.

Its specific gravity is 1·25. It boils at a heat under 122°. It burns with a red flame, green round the edges. Ammonia decomposes it immediately, and water in a few days. It is composed of

1 atom chloride of cyanogen .	$C^2\ Az\ Ch$
1 atom methylene . . .	$C^2\ H^3\ O$

10. *Cyanate of methylene.* This compound was formed in Liebig's laboratory, examined and analyzed by Mr Richardson in 1837. It was obtained by passing liquid cyanic acid into pyroxylic spirit. The cyanate of methylene was deposited in the state of a white crystalline powder.

Its characters and composition are stated by Mr Richardson to be the same as those of cyanic ether. It must then be $C^2\ H^3\ O + 2\,(C^2\ Az\ O) + 3\,(H\ O)$.

M. Laurent has formed elaidate of methelyne, margarate of methylene, and oleate of methylene, by processes similar to what has already been described. For the characters of these compounds I refer the reader to Laurent's paper.‡

Acid compounds of methylene. The first of these formed by

* Ann. de Chim. et de Phys. lxiii. 52. † Ibid. lxiv. 222. ‡ Ibid. lxv. 296.

Dumas and Peligot they have distinguished by the name of *sulphomethylic acid.* It is obviously an acidulous salt, similar to *althionic* acid in its composition. This acid, together with tartromethylic and racemomethylic, the only ones hitherto examined, have been described in a preceding Chapter of this volume.

Sulphamethylane. When a current of dry ammoniacal gas is passed through pure sulphate of methylene, the liquid becomes very hot, and is gradually converted into a soft crystalline mass, which is probably a mixture of sulphate of methylene and *sulphamethylane.* To obtain this last compound it is merely necessary to treat sulphate of methylene with liquid ammonia. When the two liquids are agitated together a violent action takes place, and the sulphate of methylene disappears.

The liquid which remains after the reaction, being evaporated *in vacuo*, yields crystals of sulphamethylane, in large and beautiful plates. It is so deliquescent that it is difficult to preserve these crystals.

The analysis is difficult, but Dumas and Peligot think it probable that it is composed of

1 atom anhydrous sulphate of ammonia
1 atom anhydrous sulphate of methylene.

Oxamethylane. When a current of ammoniacal gas is passed through oxalate of methylene, a slight heat is evolved, but to produce the proper reaction, the oxalate of methylene must be kept in a state of fusion. The liquid gradually becomes solid, and becomes at last a white crystalline matter. When dissolved in boiling alcohol and allowed to cool, it crystallizes in cubes with pearly faces.

The constituents of this substance, according to the analysis of Dumas and Peligot, are

Carbon	34·47
Hydrogen	5·06
Azote	13·90
Oxygen	46·57
	100·00

These proportions give the following atomic constituents :—

6 atoms carbon	= 4·5	or per cent.	34·95
5 atoms hydrogen	= 0·625	— —	4·85
1 atom azote	= 1·75	— —	13·59
6 atoms oxygen	= 6·00	— —	46·61
	12·875		100

These numbers are resolvable into

1 atom oxalic acid .	C^2	O^3		
1 atom methylene .	C^2	O	H^3	
forming 1 atom oxalate of methylene	C^4	O^4	H^3	
1 atom oxamide . .	C^2	O^2	+ H^2 Az	
	C^6	O^6	H^5 Az	

Thus we see that the oxamethylane is a compound of

1 atom oxalate of methylene .	7·375
1 atom oxamide . . .	5·5
	21·875*

CHAPTER IV.

OF ACETONE.

This is the name by which the pyro-acetic spirit of Chenevix is distinguished by modern chemists.

It appears from a quotation of Proust, that acetone was first observed by Beccher. He obtained it by distilling acetate of lead, and considered it as alcohol regenerated.† Proust himself had obtained it, and he notices some of its most remarkable properties‡ in his remarks on Fourcroy's *Systeme des connoissances Chimiques*, which were published in 1802. He mentions also that it had not been overlooked by Baumé; and that Bernard Pluvinet, in his dissertation *de fermentatione spirituosa et acetosa*, had given a detailed account of its properties.

It was obtained by Trommsdorf in 1805, by distilling acetate of soda, and this chemist described its properties at considerable length.§ But Derosne was probably the modern chemist who first drew the attention of men of science to it. He obtained it during the distillation of verdigris in 1807, and determined its most remarkable properties.‖ Chenevix examined it again in 1809, determined the proportion of it furnished by the different acetates, and ascertained almost all its remarkable properties.¶

Nothing farther was added to our knowledge of it till 1823, when it was subjected to a chemical analysis by MM. Macaire and Marcet,** in order to determine its chemical constitution; but as these gentlemen give us no means of judging of the purity of the liquid which they subjected to analysis, the value of their experiments is thereby much diminished. Another analysis of it was made by Matteucci in 1831,†† and in 1832 it was examined and analyzed successively by Liebig‡‡ and Dumas.§§

Acetone is usually obtained by distilling acetate of lime. Thus

* Ann. de Chim. et de Phys. lxi. 60.

† Unde contingit quod si spiritus aceti cum plumbo in concluso vase distilletur, non amplius spiritus aceti, sed rursus spiritus vini ardens in lucem prodeat depositâ priori larvâ salinâ medianteque aceti spiritus vocabatur.

‡ Jour. de Phys. lvi. 208. § Gehlen's Jour. v. 578.

‖ Ann. de Chim. lxiii. 267. ¶ Ibid. lxix. 5.

** Bibliotheque Universelle, Oct. 1823. Annals of Philosophy (Second Series), viii. 71.

†† Ann. de Chim. et de Phys. xlvi. 429. ‡‡ Ibid. xlix. 195. §§ Ibid. p. 208.

prepared, it requires to be rectified repeatedly over dry chloride of calcium over a water-bath, till its point of ebullition becomes steady.

It is a colourless liquid, very fluid, and has a peculiar aromatic odour. Its specific gravity, when pure, is 0·792, as determined by Liebig* and Dumas.† The following table exhibits the specific gravity of this liquid, as obtained by the different experimenters:—

Derosne	0·79
Proust	0·88
Chenevix	0·78
Trommsdorf	0·75
L. Gmelin	0·822
J. Liebig	0·7921 at 64°½

When pure it boils, according to Liebig, at 132°; according to Dumas, at 133°.‡ The density of its vapour, as determined by Dumas, is 2·019.

Soluble in all proportions in water, alcohol, and ether—takes fire readily, and, like ether, gives out much light when burning—not altered by exposure to the air, provided it be not allowed to fly off in vapour—not altered by alkalies—has no action on chloride of calcium.

When distilled with chlorite of lime, it forms *chloroform*.

When chlorine gas is passed into acetone, the liquid becomes hot, much muriatic acid is formed, and the liquid assumes a greenish-yellow colour. But the reaction soon ceases, unless the liquid be kept boiling-hot during the passing of the chlorine gas through it. When mixed with sulphuric acid, an oily liquor separates, which may be decanted off, and rectified over quick lime. It has an amber colour, is insoluble in water, has a peculiar penetrating smell, and a specific gravity of 1·33. According to Dumas, its constitution may be represented thus:—

3 atoms carbon	= 2·25	or per cent.	28·125
2 atoms hydrogen	= 0·25	— —	3·125
1 atom chlorine	= 4·5	— —	56·25
1 atom oxygen	= 1	— —	12·5
	8		100·0

The constituents of acetone, as determined by the analysis of Liebig and Dumas, are as follows:—

	Liebig.	Dumas.				
Carbon	61·28	61·29	or 3 atoms =	2·25	or per cent.	62·07
Hydrogen	11·29	10·10	or 3 atoms =	0·375	— —	10·34
Oxygen	27·43	28·61	or 1 atom =	1	— —	27·59
	100·00	100·00		3·625		100

* Ann. de Chim. et de Phys. xlix. 196.

† Traité de Chimie appliquée aux Arts, v. 180.

‡ Chenevix states the boiling point to be 138°, while L. Gmelin makes it 133°¼.

Now, if from an atom of acetic acid .	$C^4\ H^3\ O^3$
we substract an atom of carbonic acid	$C\ \ O^2$
The remainder will be . . .	$C^3\ H^3\ O$

which is equivalent to the constituents of an atom of acetone. Hence acetone seems to be acetic acid, minus an atom of carbonic acid.

If we multiply the constituents of acetone, as above determined, by 4, we get . . . . . $C^{12}\ H^{12}\ O^4$

Now these quantities may be resolved into

1 atom acetic acid . .	$C^4\ H^3\ O^3$
1 atom water . . .	$H\ O$
1 atom octo-carbohydrogen	$C^8\ H^8$
	$C^{12}\ H^{12}\ O^4$

This is the view of the constitution of acetone, taken by Dumas. But I consider it as very unlikely to be correct. The specific gravity of the vapour of acetone was found by Dumas to be 2·019. Now, the specific gravity of

3 volumes carbon is . .	1·25
3 volumes hydrogen . .	0·2083
½ volume oxygen . . .	0·5555
	2·0138

Were we to adopt Dumas' opinion, it would be necessary to consider the vapour of acetone to be composed of

1 volume vapour of acetic acid	= 3·5416
1 volume octo-carbohydrogen	= 3·8888
1 volume vapour of water	= 0·6250
	4)8·0555
	2·014

united together and expanded into 4 volumes. But this is an alteration of bulk that has nowhere hitherto been observed in gaseous combinations.

Acetone resembles ether in its mode of burning. But as it unites in all proportions with water, it must rather be considered as a species of alcohol than of ether.

M. Fremy discovered that when 1 part of sugar is intimately mixed with 8 parts of unslacked lime, and distilled, the product consists of two liquids, one of which is acetone, and to the other he has given the name of *metacetone*.*

The metacetone, when purified, is a colourless liquid, which boils at 183°. It is insoluble in water; but soluble in alcohol and ether, and has an agreeable smell. The purification of it is at-

* Ann. de Chim. et de Phys. lix. 5.

tended with considerable difficulty. M. Fremy analyzed it, and obtained

Carbon	72·37 or 6 atoms	= 4·5	or per cent.		73·47
Hydrogen	10·15 or 5 atoms	= 0·625	—	—	10·20
Oxygen	17·48 or 1 atom	= 1	—	—	16·33
	100	6·125			100

$5\frac{1}{2}$ atoms carbon would come nearer the analysis than 6 atoms.

Now sugar is a compound of C^{12} H^{11} O^{11}, and

3 atoms acetone are	C^9	H^9	O^3
3 atoms carbonic acid	C^3		O^6
2 atoms water		H^2	O^2
	C^{12}	H^{11}	O^{11}

Thus we see, that an atom of sugar is resolvable into 3 atoms acetone, 3 atoms carbonic acid, and 2 atoms water. The carbonic acid remains in combination with the lime.

To perceive how the metacetone is formed, we have

2 atoms sugar	C^{24}	H^{22}	O^{22}
3 atoms metacetone	C^{18}	H^{15}	O^3
6 atoms carbonic acid	C^6		O^{12}
7 atoms water		H^7	O^7
	C^{24}	H^{22}	O^{22}

So that 2 atoms sugar must be resolved into 3 atoms metacetone, 6 atoms carbonic acid, and 7 atoms water.

CHAPTER V.

OF MESITE.

This substance was discovered by Reichenbach among the products of the distillation of wood, and the account of it published in the year 1834.* It was obtained in the following way:—Eleven hundred pounds of tar from beechwood were distilled in an iron still by a very low heat. There came over at first a light-yellow oil. This was followed by an acid aqueous liquor. These two products came over together or separately, according as the heat was higher or lower. When about $4\frac{1}{2}$ imperial gallons had been distilled over, the product was neutralized by the addition of dry carbonate of potash, of which an unexpectedly large quantity was requisite. In consequence of this saturation, a considerable quantity of oil separated from the watery liquid. The whole liquid was distilled over the water-bath, till no more oily liquid passed over.

* Schweigger—Seidel's Jour. Bd. ix., and Annalen der Pharmacie, x. 298.

It appeared now bright yellow, clear, had a spirituous smell, left, when rubbed on the hands, a peculiar smell, and was not acid.

To separate the watery liquid, and to free it from creasote, picamar, and the yellow colouring matter, it was mixed with an excess of slacked lime, and distilled again over the water-bath. The oil was now colourless, and had a purer spirituous smell. When exposed to the air for some days, it assumed a yellow colour. To deprive it of this colour, it was once more distilled off lime. To separate it from eupion, it was well agitated with 15 times its bulk of water. The greater part dissolved in that liquid, but a small portion separated and swam on the surface. It consisted of eupion, and another substance hitherto unknown.

The aqueous solution was distilled on the water-bath, and what passed over was treated with chloride of calcium, to free it from pyroxylic spirit, and water till it ceased to communicate moisture. It was then distilled over chloride of calcium by the water-bath.

The liquid thus obtained had considerable resemblance to eupion, but its chemical properties were quite different. M. Reichenbach gave it the name of *mesite*.*

It is colourless, has a very aromatic and spirituous smell, when the vapour is drawn into the lungs it has a stifling effect. The taste is burning, followed by a cooling impression. It is as liquid as ether, and as volatile as alcohol. It boils at 143°·5, and has a specific gravity of 0·805. When brought near a candle, it burns with a light yellowish flame, with a shade of blue, without smoke, and without leaving any residue.

It dissolves in all proportions in alcohol and ether. Two parts of water dissolve 1 part of mesite, and 2 parts mesite dissolve 1 part of water. Alkalies do not combine with it, nor do they occasion any alteration in its properties. Sulphuric acid mixes with it, and occasions the evolution of so much heat that the liquor boils. It becomes brown, and is decomposed without the formation of any ether. Chlorine gas is absorbed by it rapidly, and in great quantity. The liquid neither loses its fluidity, nor acquires colour, yet its appearance is altered. This chloride does not dissolve in water.

Reichenbach considers mesite as identical with acetone; but the properties, which he has ascertained, are too different from those of that body, to permit their being confounded. Mesite, however, is a substance well entitled to a further examination. It has a certain analogy to pyroxylic spirit; but is obviously different from that substance.

* From μεσιτης, a *mediator*. He considered it as *acetone*. It is not easy to see the meaning of the term *mesite*, as applied to this substance.

CHAPTER VI.

OF COLOURING MATTERS.

This Chapter comprehends the numerous tribe of vegetable substances employed as dye-stuffs. Of course those only can be introduced here which have been examined by chemists; and only a small number of the most important of the common dye-stuffs are in this predicament. This order of vegetable bodies will experience much increase hereafter, especially in those nations on the continent, where men of science are appointed to superintend and improve the processes of dyeing and calico-printing. The numerous colouring matters from the mineral and animal kingdoms are omitted here, because we are treating of vegetable bodies only.

Several of these colouring matters possess decidedly acid properties. But in the present state of our knowledge we cannot arrange them among acids; because we do not know that they all possess acid characters.

DIVISION I.—OF BLUE COLOURING MATTERS.

Blue colouring matters, from the vegetable kingdoms, are not numerous; scarcely any other except *indigo* being employed by the dyer. We shall notice, also, *litmus*, because it is used as a chemical reagent, and make a remark or two on the colouring matter of blue flowers.

SECTION I.—OF INDIGO.

1. The pigment known by the name of indigo, is obtained from the leaves of the *indigofera*, a genus of leguminous plants found in India, Africa, and America. There are about sixty species of indigofera, which have been described by botanists, all of which yield *indigo;* but the species from which it is usually extracted are the *anil*, the *argentea*, and the *tinctoria*. The plant lives about ten years; but the leaves, when the plant is only one or two years' old, have been found to yield more indigo than the leaves of older vegetables, and, therefore, are preferred. Indigo is not confined to the indigofera. Dr Roxburgh drew the attention of manufacturers to the *nerium tinctorium*, a tree very common in Hindostan, from the leaves of which it may be extracted. The *isatis tinctoria* also, a native of Great Britain, contains it, though but in small quantity, and was employed in dyeing blue before the introduction of indigo into Europe as a dye-stuff.

Indigo was probably known in Hindostan, and even employed as a dye-stuff at a very early period. But to the Greeks and Romans it was known only as a paint. Dioscorides* and Pliny† mention it under the name of *indicum*, and inform us that it was brought

* Lib. iv. c. 57, or 104, according to some copies. † Hist. Natur. lib. xxxv. c. 6.

from India. The descriptions of both so nearly agree, that it is probable Pliny, who dedicates his book to Titus Vespasian, borrowed his account from Dioscorides, who is supposed to have written in the time of Nero; though he does not give the name of Dioscorides in the list of authors whom he consulted. They inform us that there are two kinds of indigo, one which is formed spontaneously, like a froth upon Indian reeds. The other kind, says Dioscorides, comes from the workshops of dyers attaching itself to the vessels, from which it is removed and dried.* This, I think, shows that indigo was used as a dye-stuff in India, and that Dioscorides was aware of it.†

Be that as it may, the value of indigo as a dye was not known in Europe before the middle of the 16th century. It is not even mentioned in the *Plictho*, a celebrated work on *dyeing*, published in Italy in 1548. The Dutch first imported it from India, and made its valuable qualities known in Europe. Even as late as the middle of the 17th century, its use was restricted in different countries. It was prohibited in England during the reign of Queen Elizabeth, and the prohibition was not taken off till the reign of Charles II. It was prohibited also in Saxony. In the edict it is spoken of as a corrosive substance, and called *food for the devil.* Colbert restricted the French dyers to a certain quantity of it.

Soon after its importance as a dye-stuff began to be generally understood, it was cultivated in Mexico and the West Indies with such success, that the indigo from these countries was preferred to every other. But towards the end of the 18th century it began to be cultivated in British India; and the culture was carried on so successfully, that East Indian indigo soon recovered its original character, and being furnished to the dyers at a cheaper rate than that from Mexico and the West Indies, it has in a great measure superseded the indigo from these countries, Hindostan at present supplying almost all the indigo employed by the dyers or calico-printers in the various countries of Europe.

The dyeing principle of indigo resides in the leaves, and is most abundant when the plant is in blossom. At a later period the indigo extracted is more beautiful, but smaller in quantity.

For the first accurate account of the process for extracting indigo from the leaves of the indigofera, we are indebted to Labat.‡ Since his time some improvements have been introduced into the manufacture; but the mode of rearing the plants still continues the same. In the West Indies the seeds are sown in March, in

* Alterum infectoriæ dant officinæ et est spuma purpurea innatans cortinis, quam detractam artifices siccant.

† Dr Bancroft (on *Permanent Colours*, i. 97) informs us that Dioscorides considered indigo as a stone; but the passage just quoted shows that this is a mistake.

‡ Jean Baptist Labat was a monk of the order of St Dominic, who, in 1693, went to America as a missionary. On his return to France, he published "A New Voyage to the American Islands," in 6 vols. duodecimo. It is in this book that his account of the manufacture of indigo is to be found. See also Lewis' edition of Newman's Chemistry, p. 435, where Labat's account is transcribed.

trenches about a foot asunder, and the plant blossoms, and is fit for cutting in May; but in South America, about six months elapse before it can be cut. In the West Indies four cuttings are often obtained from the same plant in the course of a year; but in America never more than two, and sometimes only one.

Indigo began to be cultivated by British settlers in India soon after the peace of 1783. At the beginning of this undertaking, and during the inexperience of Europeans, added to the unskilfulness of the natives, the indigo had to enter the European market in competition with that of the French and Spaniards, in the height of its abundance, arising from extensive capitals and matured experience. The indefatigable exertions of the indigo planters enabled them, in some measure, to overcome these difficulties; and the destruction of St Domingo, at the beginning of the French Revolution, suddenly withdrew the competition of the French planters, and left the market of Europe open to the enterprising cultivators of indigo in Hindostan. The consequence was a prodigious increase of the produce, as much, it is said, as three or four millions of pounds annually. The consequence was a diminution of the price, and the ruin of many of the manufacturers. The most general method adopted in India is agreeing with the natives for what quantity of the plant they can produce, and bring to the work at a fixed price. An acre of ground produces only, at an average, about ten pounds of indigo. But the price of labour is so low in Hindostan (about $\frac{1}{6}$th of what a West Indian negro costs), that the raisers of indigo, even though their produce be less in quantity than in other countries, are enabled to sell their indigo at a price which defies competition.*

In Bengal the plant is cut before flowering, at which time it is in its highest state of perfection. When cut it is tied up in bundles, about $5\frac{1}{4}$ feet in circumference, and carried, as quickly as possible, to the factory. If it be kept for a very short time, and more especially if in heaps, a sort of fermentation takes place, completely destroying the indigo.

With these bundles a large *vat* is filled, and they are strongly pressed down by means of bamboos, and a stout cross-beam. The whole is then covered with water, and allowed to steep for a period of from 9 to 12 hours, according to the skill of the planter, and the state of the weather. This part of the process requires care. If the plants be steeped too long, the indigo will be much damaged, or *burnt*, as it is termed by the planters. If they be steeped too short, the quantity of produce is much diminished.

The yellow-coloured liquor (too long steeping renders it reddish) is drawn off, by means of a plug at the bottom of the vat, into another similar vessel, where it is beat and stirred with bamboos until it granulates, which generally takes from $1\frac{1}{2}$ to 3 hours, and requires, especially towards the end, the greatest care and attention to stop the beating at the instant the grains have become com-

* Tennant's Indian Recreations, ii. 143.

pletely formed, and separated from the mother liquor. If the beating be continued for too short a time, a part of the contents will be lost; if it be continued too long the grains will be again broken down, and it will be with the greatest difficulty, if at all, that they can be separated from the liquid.

When the workman considers that the grains are properly formed, a few pailfuls of cold water, or sometimes of lime water, are added, the whole is then gently stirred with a circular motion, and the fecula allowed to subside. The supernatant liquid is drawn off, and the blue precipitate at the bottom (being previously washed with clean water, if lime water had been mixed with it) is removed into a copper boiler till it assumes the appearance of effervescing, or till it *ferments*, as the planters term it. Some planters do not boil, but only keep it milk-warm, till the same appearance takes place. When boiling is used the indigo is much lighter, or more bulky, than when the liquid is merely kept warm.

It is then placed upon a bamboo frame, covered with cloth, in the form of a filter, and all the liquor that will is allowed to drain from it. It is then placed in proper frames, and strongly pressed by means of screws, then taken out and cut into cakes of the proper size, and placed in the drying-house. In some districts it is now ready for the market. But farther up the country it is in this state loosely packed in boxes, with a layer of coarse hemp, or some similar material, placed between each layer of cakes. Being allowed to stand for some time it becomes hot, and a quantity of moisture is exuded, or in the language of the planters, *the crude and bad humours are sweated out.* It is now again placed in the drying-house, and when thoroughly dry, packed up and sent to market.

One beegah (the third of an acre) of land, in an average season, yields 20 bundles, each 5½ feet in girth. The usual price paid in Jessore to the ryots is one shilling and ten pence halfpenny, for eight bundles.

The leaves of the indigofera yield a green infusion to hot water, and a green powder may be precipitated from it; but unless a fermentation has taken place, neither the colour nor the properties have any resemblance to those of indigo. There is little doubt that in the leaves it exists in the state of *white*, or *deoxygenized indigo*, and that during the fermentation it combines with the requisite quantity of oxygen to convert it into *blue indigo*. The evolution of carbonic acid renders it not unlikely that the *white indigo* was in combination with some principle (probably of an alkaline nature), which was decomposed during the fermentation.

Dr Roxburgh's process for extracting indigo from the leaves of the *nerium tinctorum* is shorter. The leaves are kept in a copper full of water, supported at the temperature of 160°, till they assume a yellow hue, and the liquid acquires a deep-green colour. The liquid is then drawn off, agitated in the usual manner, and the indigo thrown down by lime water.*

* Bancroft on Permanent Colours, i. 423.

Indigo may be obtained also from the *isatis tinctoria*, or *woad;* a plant cultivated in Britain, and even occurring wild.* When arrived at maturity this plant is cut down, washed, dried hastily in the sun, ground in a mill, placed in heaps, and allowed to ferment for a fortnight. It is then well mixed and made up into balls, which are piled upon each other and exposed to the wind and sun. In this state they become hot, and exhale a putrid ammoniacal smell. The fermentation is promoted, if necessary, by sprinkling the balls with water. When it has continued for a sufficient time the *woad* is allowed to fall to a coarse powder, in which state it is sold as a dye-stuff. By treating woad nearly in the same way as *indigofera*, indigo has been obtained from it by different chemists. Justi† was one of the first of these; Barth published a paper on the subject, in 1754;‡ Kulencamp,§ in 1755; and Edel‖ a third, in 1756. Several experiments on the same subject have been made in Germany since the commencement of the present century.¶

Indigo, in the state in which it occurs in commerce, is far from being pure; more than half its weight consisting of matter destitute of a blue colour, and incapable of being used as a dye-stuff. Bergman showed, long ago, that 100 parts of the indigo of commerce contained only 47 parts of pure indigo, the rest being earthy matter, or oxide of iron, or gum, or resin.** Part of these impurities may be dissolved by water, part by alcohol, and part by dilute acids and by alkaline leys. Berzelius found that the indigo of commerce, besides the blue pigment, contains: 1. A substance analogous to gluten, which may be obtained by digesting indigo in dilute sulphuric acid. 2. A *brown* matter, which may be dissolved by concentrated potash ley; and, 3. A red resinous substance, which may be dissolved in alcohol.††

The best way of obtaining pure indigo, is to have recourse to the calico-printer's vat, in which the indigo has been deprived of its blue colour by sulphate of iron, and is held in solution by means of lime water. The colour of this solution is yellow. If a quantity of it be put into an open vessel it absorbs oxygen from the atmosphere, and the indigo precipitates of a blue colour. If the precipitate be digested in muriatic acid, washed, and dried, it is pure indigo.

It has been long known that when indigo is heated it sublimes. Mr Crum informs us that this fact was first mentioned in a work on calico-printing, published in 1789, by Mr O'Brien, a pattern-

* The *vitrum* of Cæsar (De Bello Gallico, v. c. 14), with which, he says, the Britons painted themselves blue, is generally considered as *isatis tinctoria*. Pliny uses the word *glastum*, with which he says the Britons stained themselves *black* (Hist. Nat. lib. xxii. c. 1). The word γλαστον is also used in the Greek translation of Cæsar.

† Schreber's Sammlungen, i. 68. ‡ In the Halle Newspaper.

§ Schreber's Samm. viii. 448. ‖ De indo Germanico ex glasto.

¶ See Saltzer, Schweigger's Jour. iii. 417; Gehlen, ibid. v. 191, and vi. 1, and viii. 136.

** Opuscula, v. 36. †† Traité de Chimie, vi. 53.

drawer, in London, who gives a method for collecting the sublimate.*

Mr Crum, after in vain endeavouring to sublime indigo by the process of Chevreul,† found the following method to answer:—He employed the covers of two platinum crucibles, nearly 3 inches in diameter, and of such a form, that when placed with their concave sides inwards, they were about three-eighths of an inch distant in the middle. About the centre of the lower lid were placed thinly about 10 grains of indigo, precipitated from the dyer's vat, not in powder, but in small lumps of about a grain each; then having put on the cover, the flame of a spirit-lamp was applied beneath the indigo. In a short time the indigo began to melt, and the vapour to be disengaged, which was known by the hissing noise that accompanied it. The heat was continued till the noise nearly ceased, when the lamp was withdrawn, and the apparatus allowed to cool. The sublimed indigo, upon removing the cover, was found planted on its inner surface, with sometimes a few long needles upon the bottom of the apparatus, which were easily removed from the button of charry matter that remained. In this way he obtained from 18 to 20 per cent. of the indigo employed.‡ When 10 grains of precipitated indigo were sublimed in this way, Mr Crum obtained

1·88 grain sublimed indigo,
6·44 grains of cinder remained, and consequently
1·68 grain of volatile matter escaped.

10·00

Thirteen grains of the same indigo, kept a quarter of an hour at a strong red heat in a small platinum crucible, firmly, though not exactly closed, left 7·9 grains of cinder, which is equal to 61 per cent.

Indigo sublimes in long flat needles, which readily split when bruised into four-sided prisms. Viewed at a particular angle they have the most brilliant and intense copper colour; but when lying in heaps they have a rich chestnut-brown colour. Besides these needles, indigo is formed in plates, much broader than the needles, and extremely thin, twisted sometimes almost into tubes. When viewed obliquely through a microscope they appear opaque, and copper-coloured like the needles; but when held perpendicular to the rays of light, they are seen to be transparent, and of a beautiful blue colour.

The vapour of indigo is transparent, and of a most beautiful reddish-violet colour, resembling the vapour of iodine, but distinguished from it by the shade of red. The sublimation takes place at the temperature of about 550°. The melting point of indigo, its point of volatilization, and that at which it is decomposed, are remarkably near each other.

* Annals of Philosophy (New Series), v. 81.
† Ann. de Chim. lxvi. 24.
‡ Annals of Philosophy (Second Series), v. 82.

The specific gravity of sublimed indigo is 1·35.

The crystals of indigo sublime when heated in open vessels, leaving no residue. In close vessels the vapour is at first reddish-violet, as in the open air; but as the heat advances it aquires a tinge of scarlet, and before it is entirely decomposed, becomes deep-scarlet, and then orange-coloured: a quantity of charcoal is at the same time deposited.*

Indigo is destitute both of taste and smell, and has neither the characters of an acid nor a base. When heated on platinum foil it gives a beautiful purple smoke; and if the heat be rapidly augmented it fuses, boils, catches fire, and burns with a lively flame, giving out much smoke, and leaving a quantity of charcoal, difficult to burn, but which may be entirely consumed without leaving any residue of ashes.

It is insoluble in water. When alcohol is boiled over it the liquid assumes a blue colour, but gradually lets fall a very minute quantity of indigo, and becomes colourless. Olive oil, and oil of turpentine, as was ascertained by Mr Crum, act precisely in the same way. Indigo is insoluble in ether. Neither dilute acids nor alkaline leys dissolve it.

Chlorine instantly destroys the blue colour of indigo, and gives it the colour of rust of iron. Iodine does not act sensibly in the humid way; but when the mixture of these two bodies is heated the blue colour is destroyed. Neither sulphur nor phosphorus combines with indigo. When a mixture of either of these bodies with indigo is heated, the sulphur or phosphorus sublimes in the first place, after which the indigo also is reduced into vapour; but no action between them takes place.

When an alkaline base, and any substance having a strong affinity for oxygen, are placed at once in contact with indigo, it is deprived of oxygen, assumes a white colour, and combines with the alkaline base. Thus protosulphate of iron and quick lime, mixed with indigo, constitute the calico-printer's vat. The oxide of iron is oxidized at the expense of the indigo, and the deoxidized indigo combines with the lime, and forms a yellow solution.

Concentrated sulphuric acid, especially the fuming acid of Nordhausen, dissolves indigo immediately, with the evolution of heat, but without the formation of any sulphurous acid. By this solution the indigo undergoes a remarkable change; being converted into the substance to which Mr Crum has given the name of *cerulin*.

Nitric acid decomposes indigo with great rapidity, destroying the yellow colour, and producing two new acids, distinguished by the names of *indigotic* and *carbazotic* acids.

The first accurate analysis of indigo was by Mr Crum. It was afterwards analyzed by Royer and Dumas, and still more lately the analysis has been again repeated by Dumas, with much care. The following are the results of these analyses:—

* Crum, Annals of Philosophy (Second Series), v. 82.

	*	†	‡
Carbon .	73·22	71·71	71·75
Hydrogen	2·92	2·66	4·05
Azote .	11·26	13·45	10·80
Oxygen .	12·60	12·18	13·40
	100	100	100

If we adopt the result of Dumas,§ which is the mean of four experiments, made with great care, upon sublimed indigo purified by alcohol, we have the following:—

15 atoms carbon	= 11·25	or per cent.	72
5 atoms hydrogen	= 0·625	— —	4
1 atom azote	= 1·75	— —	15·2
2 atoms oxygen	= 2·00	— —	12·8
	15·625		100

Dumas has more lately resumed the investigation, and he assures us that by at least thirty analyses, he has ascertained that sulphoindigotic acid is composed of $C^{16}\ H^{5}\ Az\ O^{2} + 2\ (S\ O^{3})$. According to this view of the subject, indigo is composed of

16 atoms carbon	= 12	or per cent.	73·28
5 atoms hydrogen	= 0·625	— —	3·82
1 atom azote	= 1·75	— —	10·69
2 atoms oxygen	= 2	— —	12·21
	16·375‖		100·00

These numbers, except in the hydrogen, approach very near to Mr Crum's analysis of indigo.

It has been already observed, that when indigo is treated with something capable of abstracting oxygen, it assumes a white or yellowish-white colour, and becomes soluble in the different bases. The easiest way of obtaining the basis of indigo (as the white matter may be called), is to employ the calico-printer's vat, or if we cannot readily procure access to such a vat, we may imitate it on a small scale, in the following manner:—Put into a large phial (which must be completely filled and well stoppered) $1\frac{1}{2}$ parts of pure indigo, 2 parts of protosulphate of iron, $2\frac{1}{2}$ parts of hydrate of lime, and from 50 to 60 parts of water. Leave these substances in contact for 24 hours, agitating them occasionally. Being left at rest till the sulphate of lime and peroxide of iron have subsided to the bottom, a reddish-yellow liquid fills the phial. Draw this liquid off by a syphon previously filled with hydrogen, and mix it with dilute

* Crum, Annals of Philosophy (Second Series), v. 87.

† Royer and Dumas, Jour. de Pharm. viii. 377.

‡ Dumas, Ann. de Chim. et de Phys. liii. 174.

§ Confirmed in 1836, in a note on Indigo, read to the French Academy by Dumas. See Ann. de Chim. et de Phys. lxiii. 265.

‖ Ann. de Chim. et de Phys. lxiii. 267.

muriatic acid, in which some sulphite of ammonia has been previously dissolved. A white precipitate falls, which must be collected on a filter, while all access of atmospheric air is carefully avoided. It must be washed with boiling-hot water, holding in solution sulphite of ammonia, and dried in a close vessel heated to 212°, through which a current of dry hydrogen gas is made to pass, till the powder is quite dry. Notwithstanding all the care we can take to exclude atmospheric air, the upper surface acquires, while drying, a blue colour. But the under portion still continues white.

This white substance, which Liebig has distinguished by the name of *indigogen*, does not alter its colour in dry air; but when placed under water, it assumes a deep-blue colour, and acquires a coppery tint when dried. Indigogen dissolves in alkalies; but without neutralizing them. It is also soluble in alcohol; but insoluble in water and acids. If we fill one leg of a syphon with a solution of indigogen in lime water, and the other leg with muriatic acid, the indigogen immediately separates in thick white flocks. If we substitute nitric acid for muriatic, the precipitate becomes instantly blue, and gradually disappears altogether.

If indigogen, in solution of an alkali or lime water, be brought in contact with oxygen gas, that gas is absorbed, while indigo is regenerated, and precipitates in the usual state of a blue powder. Liebig dissolved 404 parts of indigogen in ammonia, and placed it over a mercurial trough in contact with oxygen gas. The regenerated indigo being dried in a heat of 212°, was found to weigh 455, indicating an augmentation of weight amounting to 11·38 per cent.*

If we consider the atomic weight of indigo 16·375, and admit that it contains 2 atoms of oxygen, and that indigogen is entirely destitute of oxygen, its atomic weight will be 13·625. Now, 404 : 47 (the increased weight of the indigogen) : : 13·625 : 1·58. It appears from this, that the quantity of oxygen absorbed by the atom of indigogen is only 1·58 atom, or 0·42 less than 2 atoms. I think it probable that this diminution is owing to an error in the experiment, owing to the great difficulty of preventing all absorption of oxygen by the indigogen before it is placed in contact with the oxygen gas.

But the experiments of Berzelius do not agree with those of Liebig. He found that when a solution of indigogen was mixed with that of sulphate of copper, the whole indigogen was converted into indigo, by absorbing oxygen from the salt, and that 100 parts of indigo, by this alteration, had imbibed 4·6 parts of oxygen.† Now 4·6 is very nearly $\frac{1}{5}$d of the whole oxygen contained in 100 parts of indigo. So that regenerated indigo, according to this experiment, differs from indigogen by only two-thirds of an atom of oxygen. But Liebig's experiment seems to me better entitled to confidence. The subject has been lately resumed by Dumas, who

* Ann. de Chim. et de Phys. xxxv. 269. † Traité de Chimie, vi. 101.

has subjected indigogen to a new analysis, from which he has deduced its composition to be

16 atoms carbon	= 12	or per cent.	72·73
6 atoms hydrogen	= 0·75	— —	4·54
1 atom azote	= 1·75	— —	10·61
2 atoms oxygen	= 2·00	— —	12·12
	16·50		100

According to this analysis, it is a *hydrate of indigo*, or indigo united to an atom of hydrogen. Dumas has entered into no details, so that we have no means of judging of the accuracy of his analysis, which must be difficult. But he himself places full confidence in his result.*

Chemists, however, cannot adopt his conclusions till he furnishes the details, to enable them to judge of the accuracy of the analysis.

It has been already mentioned that indigo dissolves in concentrated sulphuric acid. By this treatment it suffers a remarkable change, being converted into a blue pigment different in its qualities from indigo, with which Saxon blue is dyed. This blue substance was first accurately examined by Mr Crum, who has distinguished it by the name of *cerulin*.†

The mixture of the blue substance with sulphuric acid is a semi-fluid, which requires a considerable quantity of water to dissolve it. The cerulin is precipitated from this solution by any salt of potash, and the precipitate is a combination of cerulin and sulphate of potash. Mr Crum distinguishes it by the name of *ceruleo-sulphate of potash*. This salt is soluble in pure water; but not in solutions of potash salts.

The salts of soda form also precipitates in the solution of cerulin with sulphuric acid, and these are likewise insoluble in solutions of potash or soda, though soluble to a certain extent in pure water. When heated, these ceruleo-sulphates dissolve even in solutions of their salts. On cooling, the greater part falls down in blackish grains; a portion, however, remaining in solution. The soda compound is more soluble than that of potash.

The salts of ammonia likewise form precipitates in the sulphuric solution of cerulin, when not much diluted. The precipitate dissolves readily in hot solutions of ammoniacal salts, and again separates when cold, the whole mass becoming curdy. The precipitate seems to be a combination of cerulin with sulphate of ammonia. It is much more soluble than the ceruleo-sulphate of potash or soda. Potash and soda and their salts decompose it. Hot water dissolves it abundantly. It is soluble also in between 40 and 50 times its weight of cold water. Similar compounds may be formed with barytes, strontian, and lime, and probably with most of the bases. But the salts of magnesia have not the property of precipitating cerulin from its solution in sulphuric acid.

* Ann. de Chim. et de Phys. lxiii. 269.

† Annals of Philosophy (Second Series), v. 88.

Ceruleo-sulphate of potash has so deep a *blue* colour, that when wetted with water it appears *black*. When dry it has a shining strong copper-red colour. By transmitted light it is blue. It attracts water from the air with great rapidity. Cold water dissolves $\frac{1}{140}$th of its weight of this substance, and forms a solution so deeply coloured, that when diluted with 20 times its weight of water in a phial, an inch in diameter, it may be just seen to be translucent. Water in a wine glass containing $\frac{1}{500,000}$th of its weight of it is distinctly blue coloured.

Mr Crum found that the saturated solution was precipitated by spring water, and by every liquid tried except distilled water. Hence the presence of any foreign substance in pure water greatly diminishes its solubility. If the solution be diluted with 20 times its weight of pure water, it is still precipitated by solutions of the salts of potash, soda, lime, barytes, strontian, lead, and mercury. The addition of sulphuric or muriatic acid does not dissolve the precipitate. But neither ammonia nor any of its salts precipitate this weak solution. None of the salts of magnesia, zinc, or copper, nor the solution of alum, sulphate of manganese, perchloride of tin, sulphated protoxide or peroxide of iron, nor nitrate of silver, decompose it. It is not precipitated by any of the acids, by infusion of nutgalls, nor by gelatin. Alcohol and ether do not precipitate the weak aqueous solution, though they do not dissolve any of the dry substance. Ceruleo-sulphate of potash dissolves readily in concentrated sulphuric acid, but not in concentrated muriatic acid.

Protochloride of tin gives the solution a yellow colour, by deoxidizing the indigo. It becomes blue again by the addition of any substance, as salt of copper, capable of imparting oxygen to it.

When heat is applied to the blue substance it does not melt; no purple vapour is given off, and in consequence of its being defended by the saline matter, a strong heat long applied is requisite to reduce it to ashes.

When indigo is dissolved in sulphuric acid considerable heat is produced, but there is no evolution of sulphurous acid. The solution is at first yellow; if it be dropt into water it instantly becomes blue, and the indigo precipitates unaltered, leaving the liquid colourless. If the solution be kept undiluted for 24 hours the indigo is converted into cerulin.

Mr Crum analyzed cerulin by mixing ceruleo-sulphate of potash with oxide of copper, heating the mixture to redness, and collecting the products. He has drawn, as a conclusion, that cerulin is a compound of

1 atom indigo . . .	15·625
4 atoms water . . .	4·5
	20·125*

Such is the result of Mr Crum's experiments on the action of

* Annals of Philosophy (Second Series), v. 94.

sulphuric acid on indigo. Berzelius has taken a different view of the subject.* According to him, when indigo is dissolved in sulphuric acid a combination takes place between them, and two new acids are formed, to which he has given the names of *hyposulpho-indigotic acid*, and *sulpho-indigotic acid*. The stronger the sulphuric acid employed, the greater is the quantity of the first of these acids formed, and the smaller of the second. English sulphuric acid gives more sulpho-indigotic acid than acid of Nordhausen does. An account of these two acids has been given in a previous Section of this work, when treating of the vegetable acids. See page 197.

M. Dumas† has lately examined this solution of indigo in sulphuric acid. He finds it to possess the characters of an acid, and has given it the name of *sulphindilic acid*, and assures us that it is a compound of

1 atom indigo	16·375
2 atoms sulphuric acid . . .	10
	26·375

It has the property of combining with the bases and forming salts, some of which are capable of crystallizing.

The sulphindilate of potash crystallizes in fine silky plates, and has a deep-blue colour. It is composed of

2 atoms sulphuric acid . .	10
1 atom indigo	16·375
1 atom potash	6
	32·375

The sulphindilate of barytes separates in flocks from the hot solution while it is cooling. Its composition is precisely similar to that of sulphindilate of potash.

The purple matter which precipitates when indigo is dissolved in sulphuric acid is, according to Dumas, a compound of

2 atoms indigo	32·75
2 atoms sulphuric acid . . .	10
	42·75

It possesses acid properties and has been called by Dumas *sulphopurpuric acid*.‡

With potash it forms a purple salt composed of

1 atom sulphopurpuric acid
1 atom potash.

It is clear that these two acids of Dumas are identical with the sulpho-indigotic acid and hyposulpho-indigotic acid of Berzelius.

Sulphuretted hydrogen gas possesses also the property of reducing the indigo in these acids. Hence the reason why the liquid has a yellow colour when the sulpho-indigotate or hyposul-

* Traité de Chimie, vi. 81. † Ann. de Chim. et de Phys. lxiii. 265.
‡ Ibid. p. 266.

pho-indigotate of lead is decomposed by that gas. It even reduces the aqueous solution of these acids, provided it be assisted by raising the temperature of the liquid to 122°. This deoxidizing process is considerably opposed by the presence of an excess of acid in the liquid. The protochloride of tin produces the same deoxidizing effect when assisted by heat.

According to Mitscherlich, when these acids are saturated with a base, the sulphuric acid only combines with it, and the indigo (the *cerulin* of Crum) acts in a way similar to the water of crystallization in simple salts.

Mr Crum, in his researches on indigo, discovered, that if the action of sulphuric acid on indigo be stopped at a certain point, a new substance is formed, possessing rather singular properties. It is formed at the instant that indigo changes from yellow to blue, by the action of sulphuric acid. Mr Crum has distinguished this substance by the name of *phenicin*;* while Berzelius, who has also examined it, gives it the name of *purple of indigo*.†

Mr Crum obtained phenicin in the following manner:—He mixed 1 part of purified indigo with 7 or 8 parts of concentrated sulphuric acid in a stoppered phial, and agitated the mixture occasionally, till it became of a bottle-green colour. It was then mixed with a large quantity of distilled water, and thrown upon the filter. By continuing to wash the filter with distilled water, the liquid, which was at first colourless, became more and more blue, and after some time all the indigo which had been changed passed through. The colourless washings were thrown away. The blue liquid, which contained the phenicin, did not differ in appearance from a solution of cerulin. On the addition of chloride of potassium, the phenicin precipitated of a most beautiful reddish-purple colour, exactly similar to the colour of vapour of indigo. It was thrown on a filter, and washed with distilled water, till the liquid that passed through began to form a reddish precipitate with nitrate of silver. It was then dried.

When dry, it has a brownish-black colour. It dissolves both in water and alcohol, and both solutions are blue. It is precipitated again of its original purple colour by all saline substances whatever. Different salts possess different powers of precipitation; thus sal ammoniac, chlorate and prussiate of potash, and common salt, precipitate phenicin entirely, from about 60 times their weight of water, and nitrate, muriate, and sulphate of potash, from about 100 times their weight. Sulphates of magnesia, zinc, and copper, precipitate 2000 times their weight of a solution of phenicin; sulphate of iron, about 3000; and alum and chloride of calcium, as much as 8000 times their weight. By these precipitations the phenicin is not altered.

Acids have no effect in preventing the precipitation of phenicin by salts; and the precipitates once formed, are not redissolved in the same liquid by the assistance of heat.

* Annals of Philosophy (Second Series), v. 95. † Traité de Chimie, vi. 98.

Mr Crum subjected phenicin to a chemical analysis, and concluded from his experiments that it is a compound of

1 atom indigo	15·625
2 atoms water	2·25
	17·875

He has given us the following method of preparing phenicin in greater quantity, though not so pure:—Mix together 1 part of indigo in powder and 10 parts of concentrated sulphuric acid in a phial, and agitate for some time, till the blue colour which the indigo loses at first is completely restored. This, at the ordinary heat of summer, requires about 3 hours. At the temperature of 100°, it is effected in about 20 minutes; and indigo, mixed with sulphuric acid, at the heat of boiling water, becomes blue the instant the mixture is made. At 45°, 10 or 12 hours are necessary, and the time increases as the temperature diminishes. Pour this mixture into a large quantity of distilled water, and filter. Take the precipitate off the filter, and wash it well with distilled water, containing as much sal ammoniac as will prevent the substance from dissolving in it. Then collect it on a filter again. Dissolve the precipitate anew, in a large quantity of distilled water; heat the solution, to drive off any particles of air which might prevent the impurities from subsiding, and let it stand two or three days in a tall vessel. Then draw off with a syphon as much as may be thought perfectly clear, leaving the remainder to be washed with more distilled water. Add to the solution any alkaline salt, till the phenicin precipitate, then throw it on a filter, and wash it with distilled water till the liquid refuses to pass through.

Phenicin dissolves in the water of liquid ammonia without injury; but the fixed alkalies destroy it, though not very readily. Chloride of tin precipitates the solution, but gradually redissolves the precipitate, forming a yellow solution; and the phenicin is thrown down again of its own colour by the salts of copper. Phenicin dissolves readily in concentrated sulphuric acid, forming a blue solution; and if this be poured immediately into water, the greater part of it is precipitated again, the impurities of the acid being sufficient to prevent its solution in water. A portion is converted into cerulin, which remains in solution. When allowed to remain dissolved in sulphuric acid, it is soon entirely converted into cerulin. Consequently, in preparing phenicin by the last described process, it is impossible to prevent the formation of a certain quantity of cerulin. Such are the properties of phenicin, as described by Mr Crum, to whom we are indebted for our first knowledge of it.

The great purpose to which indigo is applied, is to dye woollen cloth, silk, linen, and cotton, blue. It constitutes a most beautiful and very fixed colour, and combines with the fibres of the cloth, without the necessity of a mordant, its affinity, especially for woollen and silk, being very considerable. But to enable it to combine with the cloth, it must be in a state of solution. Now, there are two

ways in which this state is induced. 1. The indigo is deprived of its oxygen, and reduced to the state of indigogen. Now, indigogen has the property of combining with alkaline bases, and of forming with them a compound which is soluble in water. 2. The indigo is dissolved in sulphuric acid. This is the method employed for dyeing what is called *Saxon blue*.

I. Indigo is converted into indigogen, and dissolved in various ways. It will be sufficient here to describe the methods most commonly employed.

1. The *calico-printer's indigo-vat* is made by mixing 1 part of indigo in powder with 3 parts of slacked lime, and 150 parts of water. After this mixture has been well agitated for some hours, 2 parts of pure and recently crystallized sulphate of iron are to be added. The liquor is well stirred, till the reduction of the indigo has taken place. This is known by the liquid assuming a yellow colour. The lime decomposes the sulphate of iron, setting the protoxide of iron at liberty. This protoxide being every where in contact with the indigo, abstracts its oxygen, being converted into peroxide of iron; and the indigogen, in proportion as it is formed, combines with the excess of lime present, and dissolves in the water of the vat, forming the yellow-coloured liquid. If the indigo employed were perfectly pure, the proportions indicated by the atomic weights of these different substances would be

1 part of indigo
1½ part of lime
4½ parts of sulphate of iron.

But as the indigo contains usually more than half its weight of impurity, it is obvious that half these quantities, or

0·75 lime
2·25 sulphate of iron,

will be sufficient. It is obvious from this, that the quantity of sulphate of iron used by the calico-printers for making their indigo-vat is rather too small. The slacked lime used is about twice as much as is necessary. But as it is the cheapest constituent, and as the excess does not dissolve in the water, it does little or no injury. And perhaps an excess of lime may be proper to supply the place of that which is continually converted into carbonate at the surface of the vat, and which, of course, falls to the bottom of the vat in the state of an insoluble powder.

The ingredients of the indigo-vat being thus mixed, and the indigo reduced, the vat is covered to preserve it as much as possible from the action of the air, which would revive the indigo, and precipitate it from its solution. It ought to be recollected by the calico-printer that lime has the property of forming an insoluble compound with indigogen, as well as a soluble; and that, therefore, too much lime may be injurious. The cloth to be dyed is dipt into the vat, and being drawn out is left exposed to the air. The indigogen immediately begins to absorb oxygen from the atmosphere,

and becomes blue. The mixture of the yellow and blue causes the cloth at first to appear green; and it only assumes the blue colour when the whole of the indigogen is converted into indigo. The depth of the shade of blue depends upon the number of dips to which the cloth is subjected.

2. *The orpiment vat.* This vat is made by mixing together, and raising to a boiling heat, 1 part of indigo in powder, 2 parts of potash, and 20 parts of water, adding 1 part of recently slacked lime, and lastly, 1 part of orpiment in powder. The whole is boiled for a few minutes, and then the clear liquid containing the indigogen united to the potash is drawn off. The sulphur and arsenic of the orpiment unite with the oxygen of the indigo, and convert it into indigogen.

This solution, thickened with gum or roasted starch, is employed by the calico-printers when they wish to apply the blue colour to certain portions only of the cloth by means of the block.

3. *Woad* or *pastel vat.* What is called *pastel*, and sometimes *woad*,* is a preparation of the *isatis tinctoria*. The leaves of this plant are cut, dried as rapidly as possible, reduced to powder, or rather into a paste, which is placed upon an inclined plane, furnished with conduits to carry the juice that runs out into a reservoir. Here it ferments, and swells, and cracks. These cracks are filled up by pressure, and the mass is moistened, from time to time, and every two or three days it is well kneaded by the feet. The fermentation is continued for twenty or thirty days, and then the whole is made up into cakes of from 1 to 3 lb. each, which are dried. By a second fermentation, to which it is often subjected, the quality of the pastel is improved.

Thus prepared, pastel has a yellow or greenish-yellow colour, and gives a green stain to paper. Old pastel answers better as a dye-stuff than that which is new made.

To prepare the pastel vat, 4 parts of indigo, 50 parts of pastel, 2 parts of madder, and 2 parts of potash are employed. The indigo is reduced to powder and boiled with the potash. The pastel is mixed with 2000 times its weight of water, and being heated to 194°, and kept for some time at that temperature, the indigo and the other ingredients are added, taking care to stir the whole well. Small portions of lime are added at long intervals, till $1\frac{1}{2}$ parts altogether have been added. In many dye-works, besides the madder, about half a part of bran is added. The mixture is allowed to cool slowly, while the lime in small quantities is added at intervals. By degrees the pastel and madder ferment, probably giving out gas, by means of which the indigo is deoxidized, and converted into indigogen. This fermentation continues for a very long time, and it is sufficient to add to the vat, from time to time, new matter in proportion as it becomes exhausted, to be able to continue the

* Woad is more commonly applied to the *reseda luteola*, a plant which yelds a yellow-dye stuff, to be mentioned afterwards.

dyeing processes with it for a great length of time. The use of the lime is to retain the brown matter of indigo, which dissolves in the potash in proportion as the lime falls down in the state of carbonate.

II. The solution of indigo in sulphuric acid has received the name of *Saxon blue*, because the process was discovered by Barth, at Grossenhain, in Saxony, in the year 1810. The indigo is reduced to a fine powder, and dried in a temperature of between 120° and 140°, to free it as much as possible from water. It is then added by small quantities at a time to concentrated sulphuric acid. From 4 to 6 parts of Nordhausen acid and from 8 to 12 parts of English sulphuric acid are employed to dissolve 1 part of indigo. The solution may be heated to 212° without undergoing any decomposition. But the foreign substances, with which the indigo is always contaminated, are much more easily decomposed. Hence the reason why the indigo should be added in small quantities at a time, in order to prevent the evolution of heat, which would occasion the disengagement of sulphurous acid. And this disengagement would be attended with injury to the indigo itself. When the solution is completed, the vessel containing it must be shut close, to prevent the absorption of water from the atmosphere, and left at rest for 24 or 48 hours, according to the temperature of the air. The sulphuric acid dissolves, in the first place, the foreign bodies mixed with the indigo, and acquires a yellowish-brown colour. The indigo is afterwards dissolved, and the acid assumes a deep-blue colour.

When the solution is complete the acid is poured into 20 times its bulk of water, and the whole is passed through a filter. There remains on the filter a substance which gives a green colour to water after the solution has passed through. It must not be washed, because it consists of impurities, which would injure the liquid as a dye.

When wool or cloth is digested in the blue liquid, the cerulin becomes fixed upon them, and gives them a blue colour. What remains is a yellow-coloured acid liquid, containing free sulphuric acid. If we wash the dyed cloth with a little water, and set the liquid to digest in a temperature of 104°, it becomes yellow. It contains, in solution, the gluten of indigo combined with sulphuric acid. It requires a great deal of water to wash off the whole of this matter. We know that it is all dissolved by the liquid beginning to assume a blue colour.

If we now digest the cloth in a solution of carbonate of potash, containing 1 part of carbonate to 200 parts of water, the liquid assumes a blue colour, and the cloth acquires a dirty-red colour. This is owing to the red matter of indigo which the alkali does not dissolve, and which remains fixed upon the cloth. From all this it is evident that the foreign matters in the indigo have a great effect in deteriorating the colour of Saxon blue.

The most beautiful Saxon blue is obtained by means of the cerulco-sulphate of potash of Crum, or the sulpho-indigotate of potash of Berzelius, which precipitates when potash is poured into a solution of indigo in sulphuric acid till $\frac{1}{4}$ or $\frac{1}{5}$ of the acid is saturated. The soluble blue which remains in solution is separated by the filter from the precipitate, which is allowed to drain. It is then dissolved in water and mixed with sulphuric acid. This liquor gives a very fine blue colour to wool.

To dye those tissues blue which do not combine with the blue acids of Berzelius, we may begin by steeping them in a solution of alum, or in a hot solution of chloride of barium and bitartrate of potash mixed together, and afterwards plunge them into the blue liquid. When alum has been employed, a little carbonate of potash is added to the blue acid solution; because it is necessary that it should contain an excess of alkali. It is the subsulpho-indigotate of alumina (according to Berzelius) which in this case attaches itself to the cloth and dyes it blue. When we employ a mixture of chloride of barium and bitartrate of potash, the acid solution may be used without any addition, and the dye which fixes itself on the cloth is sulpho-indigotate of barytes.*

SECTION II.—OF LITMUS, OR TURNSOLE.

Litmus, called *lakmus* by the Germans, and *turnsole* by the French, seems to have been prepared at first in Holland, and the Dutch seem still to be the manufacturers of it. It is sold in small cubical cakes of a dirty-blue colour, which are light and friable. At first it is said to have been prepared from a lichen from the Canary Islands (doubtless the *roccella tinctoria*). But at present the *leconora tartarea* is used, which is said to be chiefly collected in Norway. Probably other lichens are also employed in the manufacture.

The lichens are cleaned, reduced to powder, and passed through a seirce. This powder is mixed with putrid urine, and left for some time in vessels. The ammonia from the urine acts on the powder, a kind of fermentation is produced, and the blue colour is developed. It is probable that the urine is distilled in the first place, and only the ammoniacal solution that comes over employed in this process; for litmus contains no acid, which could hardly be the case if urine were employed in its preparation. Fourcroy and Vauquelin advanced, that litmus is naturally of a red colour, and that it is made blue by the addition of carbonate of soda to it. But Mr Smithson has shown that this is a mistake.†

There can be little doubt that the substance to which litmus owes its colour and its dyeing properties is *erythrin*, a matter which exists in *archil*, and which will be described in a subsequent Section of this Chapter. But we do not know what variation in the manufacture gives to litmus a blue colour, while archil has a red.

* Traité de Chimie, vi. 110. † Phil. Trans. 1818, p. 110.

It is known, however, that archil becomes deeper coloured by keeping; and that when old it assumes a blue colour, almost as fine as that of litmus. The erythrin in this case undergoes a notable change, for it is insoluble in water, while the blue colouring matter of litmus dissolves readily in that liquid.

The colouring matter of litmus is soluble in water and in alcohol. It has not yet been obtained in an insulated state. The concentrated infusion of litmus has a purple colour; but it stains paper of a beautiful blue. Acids change this blue colour to red, and alkalies restore the original blue colour without changing it to green. Hence it differs in its nature from the juice of red cabbage, the blue colour communicated by the petals of the violet, the blue from the skins of radishes, and, indeed, most blue vegetable colours.

Chevreul informs us that the blue of litmus is naturally coloured red by an acid at present unknown, with which it is in combination. When the chloride of barium is poured into the infusion of litmus, there is formed, he says, a blue precipitate, which, after being washed and treated with a quantity of sulphuric acid, less than what is necessary to saturate the barytes, we obtain a red acid liquor which contains no sulphuric acid.

The weakest acids, even sulphuretted hydrogen, have the property of reddening litmus. Hence its value as a reagent to indicate the presence of acids, which it does with more delicacy than any other reagent with which we are acquainted. When infusion of litmus is mixed with a solution of sulphuretted hydrogen in close vessels, and kept for several days exempt from the contact of the atmosphere, the colour disappears; but it appears again if we expose the mixture to the atmosphere, or raise it to the boiling point. The infusion of litmus is rendered colourless also by sulphurous acid, or the hyposulphites. It is obvious from these facts, that a certain analogy exists between the colouring matter of litmus and indigo. Both are capable of being deprived of oxygen; and when thus deoxidized they lose their blue colour, which is again restored by those substances, as atmospheric air, which are capable of supplying the oxygen that has been subtracted.

M. Desfosses informs us that this deoxidizement of litmus may be accomplished by the protosalts of iron. He assures us that when the infusion of litmus is mixed with a small quantity of protosulphate of iron, and some ammonia added, the liquid becomes colourless on standing, while the iron is peroxidized. On exposure to the air the blue colour is again revived. When too large a quantity of protosulphate of iron is used, the deoxidized litmus precipitates white along with the oxide of iron when ammonia is added. If we wash the precipitate, and then mix it with water, and decompose it by means of sulphuretted hydrogen gas, sulphuret of iron is formed; but the deoxidized litmus does not dissolve till we digest the sulphuret in ammonia. If we evaporate the ammoniacal solution, the colouring matter remains. It is soluble in water, but does not dis-

solve in strong alcohol. When burnt it gives out the odour of burnt feathers. Nitric acid converts it into oxalic acid.

When tincture of litmus is evaporated to dryness on the water-bath, the colouring matter remains in a dry state. When this residue is heated in a platinum spoon over a candle it swells considerably, becomes black, and smokes; but it does not readily inflame or burn away, unless the blow-pipe be applied. It then burns pretty readily, leaving a large quantity of saline matter, consisting chiefly of carbonate of potash mixed with a little lime.*

SECTION III.—OF BLUE AND RED COLOURING MATTER OF FLOWERS.

Very few accurate experiments have hitherto been made on the colouring matter which gives the beautiful blue, violet, or red colour, which distinguishes the petals of so many flowers. They readily give out their colour to water, but few of them give a blue colour to alcohol. Some give a red colour to that liquid, and some no colour whatever.† The expressed juice of most red flowers is blue. Hence it is probable that the colouring matter in the petals, is reddened by an acid which makes its escape when the juice is exposed to the air. Doubtless the acid is the carbonic. Most blue and red flowers lose their colour in drying, and become white, or rather a dirty-yellow. The more rapidly they are dried, and the more completely the air is excluded, the more of their colour they retain. The expressed juice soon fades altogether, and this happens even though the juice be mixed with an acid.

The *violet* is well known to be coloured by a *blue* matter which acids change to red, and alkalies and their carbonates first to green and then to yellow. Doubtless the *green* colour is owing to a mixture of *blue* and *yellow*. Hence the reason why alkalies change blue colours first to green and then to yellow. This same matter is the tinging principle of many other vegetables: of some in its blue state, of others made red by an acid.

If the petals of the red rose be triturated with a little water and carbonate of lime, a blue liquor is obtained. Alkalies and soluble alkaline carbonates render this blue liquor green; and acids restore its red colour.

The colouring matter of the violet exists in the petals of red clover, the red tips of the common daisy of the fields, of the blue hyacinth, the hollyhock, lavender, in the inner leaves of the artichoke, and numerous other flowers. Made red by an acid, it colours the skin of several plums. It probably also gives its red colour to the petals of the scarlet geranium, and of the pomegranate tree. The leaves of the red cabbage and the rind of the long radish are also coloured by this principle. It is remarkable that these on being merely bruised become blue, and give a blue infusion with water. It is probable that the reddening acid in these cases

* Smithson, Philosophical Transactions, 1818, p. 211.
† Lewis's Neumann's Chemistry, p. 430.

is the carbonic, which, on the rupture of the vessels which enclose it, escapes into the atmosphere.* Schubler considers the *red*, *orange-red*, *orange*, *yellowish-green* colours of flowers to be owing to the absorption of oxygen; the *bluish-green*, *blue*, *violet-blue*, *violet-red*, and *red* colours to be owing to disoxygenizement.†

DIVISION II.—OF RED COLOURING MATTERS.

The red colouring matters in the vegetable kingdom are more numerous than the blue. We shall describe the most important of them in the following Sections.

SECTION I.—OF MADDER.

Madder is the root of the *rubia tinctorum*, a plant which is cultivated in the south of Europe and the countries bordering on the Mediterranean as a dye-stuff.‡ What is employed in Great Britain comes chiefly from the Levant. The plant is cultivated also in Holland; but the Dutch madder is not considered to be so rich in colouring matter as that which comes from Turkey.

This plant was well known to the ancient Greeks and Romans. Dioscorides describes it under the name of *erythrodanon*, and mentions that it was employed as a dye-stuff; that it both grew wild and was cultivated in Italy and Asia Minor, and that in his time it was employed in medicine.§ Pliny mentions it under the name of *rubia*, but gives also the Greek name *erythrodanon*, or *ereuthodanon*.‖ It is said also by Leuchs to have been called *Vœrantia* by the Romans; and from this word he derives *garance*, the name by which madder is known in France.¶

Besides the *rubia tinctorum* there are two other species, the *cordifolia* and the *peregrina*, which yield the same red colouring matter. The former grows in Siberia, where it is used as a dye-stuff. The latter is cultivated in the countries bordering on the Mediterranean, and has been lately introduced into the south of France. It is not improbable that the madder imported into this country from the Levant consists of the roots of this last species.

The roots, which alone are employed, are called *alizari* in the Levant. They have a reddish-brown colour. Before being employed as a dye-stuff they are reduced to a powder more or less fine.

Madder, according to Kuhlmann, contains two colouring matters, one, which is yellow, is soluble in cold water. Kuhlmann, who first obtained it, has given it the name of *xanthin*.** The other, which

* Smithson, Phil. Trans. 1818, p. 112. † Jour. de Pharmacie, xvi. 392.

‡ The *rubia* of the east is not the same species as that cultivated in France and Holland; but the *peregrina* and *lucida*, which are richer in colouring matter, and require a warm climate to bring them to maturity. See Jour. de Pharmacie, xxii. 523.

§ Dioscorides, c. cxxxvii. or clx. in some editions.

‖ Plinii Hist. Nat. lib. 24, cap. 11.

¶ Leuchs' Traité complet des Matieres Tinctoriales, i. 273.

** Ann. de Chim. et de Phys. xxiv. 225.

is red, and to which madder was supposed to owe its value as a dye-stuff, was first obtained in a state approaching purity by Colin and Robiquet. They have distinguished it by the name of *alizarin*.*

To obtain *alizarin*, Robiquet and Colin recommend the following process:—Mix pounded madder with two-thirds or with its own weight of concentrated sulphuric acid, and set the mixture aside for two or three days, taking care that no heat is evolved. All the other constituents of the madder, except the alizarin, are converted into charcoal, and if heat has been extricated, even the alizarin itself is charred. Wash the black matter thus formed to extract from it all the acid; what remains is a mixture of charcoal and alizarin. Let it be dried and digested with a portion of cold alcohol, which will dissolve a fatty matter which it contains. If we now digest it in boiling alcohol, that liquid will take up all the alizarin and leave the charcoal. Mix the alcoholic solution with water, distil off the alcohol and filter the residual liquid. The alizarin remains on the filter.

Kuhlmann's process is somewhat different. He digests the madder in successive portions of cold water, till all the xanthin which is soluble has been taken up. The residue is treated with boiling alcohol till every thing soluble in that liquid is dissolved. The alcoholic solution is concentrated by distillation. It is then mixed with sulphuric acid, and finally with water. The whole alizarin precipitates mixed with some foreign bodies. The precipitate is washed, dried, and treated with ether, which dissolves the alizarin, and lets it fall as it evaporates in the form of crystals, and in a state of purity.

Alizarin thus obtained has a red colour; it is insipid and destitute of smell. According to Zenneck it possesses weakly acid properties; but Colin and Robiquet consider it as quite neutral. It may be sublimed in long flexible capillary needles, having an orange colour; but unless the subliming vessels be very low and flat, almost the whole of the alizarin is decomposed during the process. Two watch glasses applied to each other answer very well as a subliming vessel. During the process the alizarin gives out an aromatic odour like that of benzoin.

It is almost insoluble in cold water; but it is moderately soluble in boiling water, to which it communicates a rose-red colour. At the temperature of 54° 212 parts of alcohol, of the specific gravity 0·83, dissolve 1 part of alizarin. At the same temperature ether, of the specific gravity 0·73, dissolves $\frac{1}{160}$th of its weight of it. The alcoholic solution is red; that of ether yellow, or orange.

Alizarin is slightly soluble in bisulphide of carbon, oil of turpentine, naphtha, and fat oils, communicating to these liquids a reddish-yellow colour. Chlorine has little action on it; yet it injures the colour a little and makes it incline to yellow. Sulphuric acid dissolves it, and acquires at the same time a blood-red colour. Nitric and muriatic acids dissolve it, and slightly alter the shade of its colour.

* Ann. de Chim. et de Phys. xxxiv. 228.

These acids when dilute do not dissolve it. With alkalies it forms soluble compounds, having a violet or lilac colour. With alumina it forms a precipitate, which is red or reddish-brown. With the metallic oxides it forms insoluble combinations, having a violet or reddish-brown colour.

It has a marked affinity for various animal matters. It dissolves in the white of an egg, diluted with water, and if we coagulate the albumen by heat, the alizarin combines with it, leaving the liquid portion tinged yellow. Albumen, containing a portion of alizarin in solution, is precipitated by a solution of chloride of calcium; yet this salt does not precipitate uncombined albumen diluted with the same quantity of water. Phosphate of lime appears also to have a marked affinity for the colouring matter of madder. Indeed this is obvious from the well known fact that the bones of animals, which have taken for some time madder mixed with their food, are tinged red.

According to the analysis of Robiquet, alizarin is composed of

Carbon	70·09 or 37 atoms	= 27·75	or per cent. 70·70
Hydrogen	3·73 or 12 atoms	= 1·5	— — 3·82
Oxygen	26·18 or 10 atoms	= 10	— — 25·48
	100·00*	39·25	100

The experiments of Colin and Robiquet were repeated by Gaultier de Claubry and J. Persoz; but they could not dye a fixed colour upon cloth by means of alizarin. This led them to conclude that alizarin does not constitute the true colouring matter of madder. They found their attempts to extract the colouring matters from madder greatly impeded by the great quantity of gum which the root contains. This led them to conceive, that by converting this gum into sugar, the extraction of the colouring matters would be much facilitated. This they accomplished in the following way:†

Powdered madder was mixed with a large quantity of water, into which sulphuric acid, amounting to one-ninth of the madder employed, was put, and this mixture was boiled till the gum in the madder was converted into sugar. The madder was then washed, till all the sugar thus formed was abstracted. Thus freed from gum, it was digested twice in succession, in a solution of carbonate of soda, by which it was deprived of what these chemists denominate *red colouring matter*. The alkaline solutions being mixed, were neutralized by an acid. A brownish-red precipitate fell, which, after being well washed, was dissolved in alcohol. The alcohol was distilled off, and the residual liquid being evaporated to dryness, a substance remained, which they distinguished by the name of *red colouring matter*.

The madder thus deprived of its red colouring matter was digested in a hot solution of alum. The liquid assumed a fine cherry-red colour. It was filtered, and concentrated sulphuric acid, or muriatic acid in slight excess, was added to it, which produced a precipitate of a fine red colour, with a tint of orange. It was col-

* Jour. de Pharmacie, xxi. 392. † Ann. de Chim. et de Phys. xlviii. 72.

lected on a filter, and carefully washed. Being dissolved in alcohol, and evaporated, it constituted the substance which they distinguished by the name of *rose-red colouring matter*.

1. The *red colouring matter* constituted a brownish-red mass, having a brilliant fracture. It was scarcely soluble in cold water; but hot water dissolved a little of it, which was not deposited when the liquid was allowed to cool. The weak acids did not alter it. Concentrated sulphuric acid dissolved it cold, and still better when assisted by a gentle heat, without the disengagement of sulphurous acid. Nitric acid did not act on it, unless when assisted by heat. White flocks were then formed, which were conjectured to be mucic acid. Potash, soda, and ammonia dissolved it very well cold. The potash and soda solutions, which had a fine red colour, did not alter by exposure to the air; but the ammoniacal solution became muddy in proportion as the alkali evaporated. The alkaline carbonates dissolved it equally, and formed fine orange-red liquids. The acids precipitated the red colouring matter unaltered from these solutions.

Alcohol dissolved the red colouring matter even at the ordinary temperature of the atmosphere; but the solution was stronger if the maceration took place at the temperature of 104°. The solution had a deep-red colour, like the alcoholic solution of safron. When evaporated at a low temperature, it let fall a brown substance, exhibiting coppery and green tints by reflected light.

Ether dissolved it more readily than alcohol, both cold and hot. By spontaneous evaporation, a colouring matter was obtained, under the form of crystalline needles.

The red colouring matter was not sensibly soluble in an aqueous solution of alum.

When heated in a tube over a spirit-lamp, it was decomposed, giving traces of alizarin, of tar, and leaving a bulky charcoal. When cloth, previously impregnated with alum, was passed through a solution of this red colouring matter, it was dyed of a brick-red colour, destitute of beauty, but very fixed.

Chlorine did not alter the red colouring matter, but with difficulty and after long-continued action. The protochloride of tin dissolved it easily when assisted by heat, and formed a very solid compound. It dissolved also in sulphohydrate of ammonia, forming a fine brownish-red liquid. It was dissolved likewise by arseniate and arsenite of potash, silicate and aluminate of potash, unless we are to ascribe these two last solutions to an excess of alkali present.

2. The *rose-red colouring matter* was a solid matter, having a resinous fracture resembling that of gamboge. When reduced to powder it had a beautiful rose-red colour.

Sulphuric acid did not attack it. Concentrated nitric acid decomposed it cold. A yellow-coloured liquid was obtained, which deposited small crystals of oxalic acid. Diluted nitric acid did not act upon it. The caustic alkalies dissolved it without the application of heat. The solution had a fine violet colour, the intensity of

which increased as the temperature was elevated. When the liquid was saturated with sulphuric acid, the violet colour was replaced by yellowish-red. When the potash solution was left to itself, it gradually lost its colour, while a red matter precipitated. The alkaline carbonates dissolved the rose-red matter, when assisted by heat, and assumed an archil-red colour. When the liquid cooled, the colouring matter was deposited. Alum and all the soluble aluminous salts dissolved it, and the solution had a fine cherry-red colour.

It was very little soluble in water. Alcohol, even while cold, dissolved it; but the solubility was increased by heat. The solution had a beautiful cherry-red colour, and when potash was added to it, the liquid became violet-red, and after some time the colouring matter precipitated. Ether dissolved it, and the solution had a more intense red colour than the alcoholic solution. Both solutions, when evaporated, deposited the rose-red matter in needles from 4 to 5 lines in length.

Chlorine destroyed the rose-red matter more easily than the red. When heated it was decomposed with the same phenomena as the red matter, giving out a little alizarin.

Protochloride of tin had no action on it. Sulphohydrate of ammonia dissolved it cold. The solution had a deep-red colour, and the intensity increased when the liquid was left in contact with an excess of the colouring matter.

Protoxide of tin, to which a little potash had been added, dissolved any proportion whatever of the rose-red colouring matter. The liquor had an extremely brilliant red colour, and cloth macerated in it acquired a fine rose-red colour. Concentrated sulphuric acid dissolved it without the assistance of heat, and assumed a fine cherry-red colour. When water was added to the solution, the colouring matter precipitated unaltered. It was dissolved by arseniate and arsenite of potash, and also by the silicate and aluminate of potash.

Such are the characters of the two colouring matters extracted from madder by Gaultier de Claubry and J. Persoz. They seem to indicate that they are rather mixtures or combinations of various colouring matters, than simple principles. Accordingly, Dr F. Runge, who has devoted so much of his time in investigating the principles of dyeing, assures us that this is the case. According to him, madder contains no fewer than 5 different colouring matters, which he distinguishes by the names of *madder-purple*, *madder-red*, *madder-orange*, *madder-yellow*, *and madder-brown.*[*]

1. *Madder-purple* (the purpurin[†] of Robiquet and Colin) is separated from madder by the following operations:—1. The madder is well washed with water, of a temperature from 56° to 70°. 2. The madder thus washed is boiled in a strong solution of alum. 3.

[*] See an abstract of his papers on Madder, in the Records of Science, ii. 452, and iii. 44 and 135.

[†] The account of this substance is consigned in a paper by Robiquet and Colin, read to the Institute on the 30th July, 1827, but which has not been published.

Sulphuric acid is poured into the alum solution, which throws down the *madder-purple*. 4. The precipitated madder-purple is edulcorated and boiled in water, and then in muriatic acid. 5. The madder-purple thus purified is dissolved in strong alcohol. 6. The alcoholic solution is evaporated to the point of crystallization. 7. The crystallized madder-purple is again dissolved in hot alcohol, and crystallized a second time. It is now a light crystalline powder of a beautiful orange-yellow colour.

It imparts to cotton, impregnated with the alum mordant, a deep reddish-brown purple colour, when it is employed in excess. But if the cotton be in excess, the colour is bright red. A boiling solution of alum forms with it a cherry-red liquid, which is not altered on cooling, if the purple-red be not in excess. Caustic potash forms with it a fine cherry-red colour. Carbonate of soda forms with it a cherry-red solution, not altered by potash. Sulphuric acid acquires from it a bright red colour.

When cautiously heated in a glass tube, madder-purple melts into a dark brown viscid liquid, from which a vapour proceeds, which does not collect in the form of needles, but forms a brown-red viscid mass on the sides of the glass. By the addition of more heat, it may be driven along the tube, but is then decomposed, being covered with carbonaceous matter. In pure water it dissolves, and forms a dark pink-coloured liquid. In cold water it is little soluble; but when a hot solution is allowed to cool, it deposits no flocks. If the water contain lime, the madder-purple dissolves at first; but a portion of it combines with the lime, and precipitates in the form of a dark red gum. Hence, if we use in dyeing with madder-purple water containing lime, the loss of colouring matter will be very great.

Spirits, alcohol, and ether, dissolve madder-purple very readily, and form orange-yellow solutions. After the evaporation of the liquids, the madder-purple remains in the form of a bright orange-yellow crystalline powder. When water is added to a hot concentrated solution of madder-purple in spirits, a quantity of silky crystals is separated, which swim in the solution.

Dilute acids, when boiling-hot, dissolve madder-purple, forming a yellow solution; on cooling, the *purple* separates in orange-yellow flocks.

Ammonia forms with madder-purple a beautiful bright red solution, which, when printed on cotton not impregnated with a mordant, and after drying, being washed in hot water, leaves a clear pink colour. When printed on cotton, impregnated with alum mordant, and washed in hot water, a clear red is obtained.

Potash dissolves madder-purple, forming a fine cherry-red coloured liquid, and gives to unmordanted cotton, after clearing with hot water, a pink colour. With mordanted cotton, a dark-red colour is obtained.

2. *Madder-red* (the *alizarin* of Robiquet and Colin) is obtained separate from madder-purple, in consequence of its insolubility, in a

strong alum solution. After madder has been well washed with water, if it be boiled in a solution of alum, a brown-red precipitate separates containing much madder-red. If we boil this precipitate repeatedly with strong muriatic acid, then wash it well with water, and finally treat it with boiling spirit of wine, we obtain a dark brownish-red coloured tincture, which being evaporated and allowed to cool, deposits an orange-yellow precipitate. This precipitate consists of madder-red mixed with much madder-purple, which last substance is separated by boiling it repeatedly in a solution of alum as long as the liquid continues to be tinged red. The yellow precipitate thus freed from madder-purple is to be washed with water, dried, and then dissolved in ether. The ether being evaporated, madder-red is obtained under the form of a brownish-yellow crystalline powder.

It imparts to mordanted cotton, when in excess, a dark-red colour; but when the cotton is in excess, a brick-red colour is produced. It is insoluble in solution of alum.

When carefully heated in a glass tube, madder-red melts into a dark orange-coloured liquid, and is driven off in the form of a yellow vapour, which condenses into bright orange-coloured needles. By additional heat the sublimate may be driven along the tube without leaving any carbonaceous residue; showing that it is capable of a second sublimation without undergoing decomposition. It colours cotton impregnated with alumina or iron as well as madder-purple itself. The red has more brilliancy than that of the unsublimed portion.

In pure water madder-red dissolves by the assistance of heat, and forms a dark yellow solution. It dissolves with difficulty in cold water. When the hot solution cools, the madder-red is deposited in orange-yellow flocks. When the water contains lime, the solution has a purple-red colour, a bluish gum being formed.

Spirits, alcohol, and ether, dissolve madder-red, forming a reddish-yellow solution. When the solutions are evaporated, a brownish-yellow crystalline matter remains. When water is added to a hot concentrated solution of madder-red in alcohol, a quantity of silky crystals separate, which swim in the liquid.

Dilute acids dissolve madder-red, forming yellow-coloured solutions. On cooling, orange-yellow flocks separate.

Ammonia forms with madder-red a beautiful purple-red solution, which when printed on unmordanted cotton and washed (after drying) in hot water, leaves a dark-red colour without lustre. To cotton impregnated with the alum mordant, it imparts a dull-red colour. Potash ley dissolves madder-red, producing a beautiful violet-blue solution, which by an excess of madder-red passes into purple. For printing it gives no better results than the solution in ammonia.

One part of madder-red is sufficient for saturating 28 parts of cloth. If more is used the colour is not darker, and the excess remains in the vat. The addition of clay is of decided benefit.

It makes the colour considerably darker and redder. The best proportions are 132 parts of clay, 1 part of madder-red, and 22 parts of cloth. The addition of chalk is decidedly injurious.

3. *Madder-orange* is distinguished from and separated from madder-purple and madder-red by its little solubility in spirits. To obtain it let madder from the Levant be well washed with pure water, and then macerated for 16 hours in 8 times its weight of water. This brown-coloured infusion is then to be strained through muslin, and its place supplied by fresh water. This should be left for 16 hours in contact with the madder. It should then be strained and mixed with the first infusion. After from 4 to 6 hours repose, the liquor should be poured off the sediment, and the madder-orange separated by filtering through fine paper. The liquid exhibits on being stirred a quantity of small crystals of madder-orange, which remain on the filter. These should be well washed with cold water, afterwards boiled with spirits, and the solution filtered while hot. From this solution madder-orange separates on cooling. The precipitate is to be washed with spirits till it dissolves in sulphuric acid with a fine yellow colour without any mixture of red. As a test of its purity we may impregnate cotton with the tin mordant, and dye it by means of madder-orange: if the dye-stuff has been pure, the colour will be a fine nankin.

It imparts to mordanted cotton a bright orange colour when in excess, but paler when the cotton is in excess. Boiling solution of alum forms with madder-orange an orange-yellow solution, which on cooling deposits a little colouring matter.

Madder-orange, when heated in a glass tube, exhibits the same characters as madder-purple; but with this difference that the vapours disengaged are yellow, and condense into a yellow-brown mass. If this is heated again, the same phenomena appear as with madder-purple, and some charcoal is left. Caustic potash produces a dark rose-coloured solution, while carbonate of soda affords an orange-coloured liquid. Sulphuric acid produces an orange-yellow colour.

With pure water madder-orange, by the addition of heat, forms a yellow-coloured solution. On cooling some deposition takes place. In cold water the colouring matter is little soluble. When the water contains lime the solution is reddish; and its dyeing power is diminished or destroyed altogether if the quantity of lime be large.

Ether dissolves madder-orange readily. When the liquid is evaporated, the dye-stuff remains in the form of a bright yellow crystalline powder. Cold spirits dissolve it sparingly. Boiling spirits form a bright yellow solution, from which on cooling the greater part of the madder-orange is deposited. If water be added to a hot solution in spirit, small crystals separate, as with madder-red and madder-purple under the same circumstances.

Dilute acids form with madder-orange a yellowish-coloured solution: on cooling the greatest part separates. Liquid ammonia forms a red-brown solution, from which, on evaporating the ammonia,

orange-yellow flocks separate. When printed on cotton, impregnated with alum mordant, a dull orange colour remains after washing the cloth in water. Potash ley forms with madder-orange a dark red-coloured solution, which by exposure to the light becomes orange. When printed on cotton, impregnated with the alum mordant, the result is not superior to that with the ammoniacal solution. 30 parts of alumed cloth require for saturation 1 part of madder-orange. It requires therefore the greatest quantity of cloth for saturation of all the madder dyes; madder-purple requiring only 16, and madder-red 22 parts of cloth for saturation. Clay has a stronger affinity for madder-orange than alumed cloth has. Hence the reason of the bright orange-yellow which clay assumes when added to the madder dye. And hence the reason why it improves the red colour of madder. It removes, if added in sufficient quantity, the madder-orange.

4. *Madder-yellow* is characterised chiefly by its great solubility in water, and its want of disposition to combine with cotton impregnated with the alum mordant. The Dutch madder is especially rich in madder-yellow. It may be separated by digesting 1 part of Dutch madder in 16 parts of water. After the digestion has continued for 12 hours, let the solution be boiled and mixed with an equal volume of lime water. In 12 hours a dark red precipitate is formed, which besides madder-yellow contains the other constituents of madder, especially madder-orange and madder-purple. To separate these an excess of acetic acid is added to the precipitate, which dissolves the lime and madder-yellow, and leaves a red mass which must be separated by filtration. The madder-yellow mixed with acetate of lime is still rendered impure by the presence of some madder-purple. This is separated by boiling the solution with cotton impregnated with the alum mordant as long as it is coloured red or orange. A point is at last attained where the cotton acquires a bright rust colour, and the yellow liquor on evaporation, leaves not a brown-red, but a bright yellow residue. The colouring matters are then completely separated. The yellow residue is now dissolved in spirits, and the madder-yellow precipitated from its solution by means of an alcoholic solution of acetate of lead. A scarlet-red precipitate falls, which is to be edulcorated with spirits, then dissolved in water, and precipitated by sulphuretted hydrogen, by which means the madder-yellow is separated from the oxide of lead. Since cotton impregnated with alum mordant acquires only a dull nankin colour by the addition of madder-yellow, and is a very inferior dye, it is needless to dilate at any further length upon its properties.

5. *Madder-brown*, not being of any value as a dye-stuff, its properties have not been investigated with any attention.

The great use of madder is to dye cotton cloth red: and by far the finest red of all is what is known in this country by the name of Turkey-red, or Adrianople-red. The method of dyeing in this manner was discovered in India, and continued long in the undis-

turbed possession of the dyers of that extensive country. But it gradually made its way into other parts of Asia, and becoming known in the dominions of the Turks, was carried into Greece, and naturalized in their European dominions. In the year 1742, MM. Ferquet, Goudard, and d'Haristoy, brought a party of Greek dyers into France, and established a Turkey-red dyework at Darnetul, near Rouen, and at Aubenas in Languedoc. Other establishments gradually arose, and in 1765, the French government, convinced of the importance of this method of dyeing, made the processes known to the public. Many establishments were formed in various parts of the kingdom. But it appears that the only successful ones were those at Rouen. From France the Turkey-red dye gradually made its way into Alsace, Switzerland, and different parts of Germany.

The first Turkey-red work in Great Britain was established about 50 years ago in Glasgow by M. Papillon, who commenced dyeing Turkey-red in partnership with Mr Macintosh. He made an agreement with the commissioners and trustees for manufactures in Scotland that the process was to be by them published for the benefit of the public at the end of a certain term of years. This period having expired in 1803, the trustees laid a minute account of the different processes before the public. Since that period Turkey-red dyeing has been conducted in Glasgow, and probably also in Lancashire, on a very extensive scale. The number of dyers has become considerable, and the fineness of the dye has been generally admired.

For an account of the different processes, as executed in India, Greece, Bucharia, Germany, and France, the reader is referred to Leuchs' *Traité complet des Matieres Tinctoriales*, vol. i. p. 305, where they are detailed at length. It will be sufficient if the processes at present followed by the most skilful Turkey-red dyers in Glasgow be stated as concisely as is consistent with clearness. The different steps of the process are as follows:—

1. The cloth is steeped in a weak alkaline ley to remove the weaver's dressing. This is technically called the *rot steep*. From 4 to 5 lbs. of caustic potash are generally employed for every 100 lbs. of cloth. The temperature of the solution is from 100° to 120°. The cloth is kept in the steep for 24 hours, and then well washed.

2. From 7 to 10 lbs. of carbonate of soda are dissolved in a sufficient quantity of water to keep the cloth (always supposed to be 100 lbs.) wet. In this solution the cloth is boiled for some time.

3. It is upon the third process that the beauty of the colour depends more than on any other. Without it the dye cannot be produced on new cloth. But when old cotton cloth that has been frequently washed (a cotton shirt for example) is to be dyed, this process may be omitted altogether.

A liquor is composed of the following ingredients:—

1 gallon Gallipoli oil,

1½ gallon of soft sheep's dung,
4 gallons of a solution of carbonate of soda, of the specific gravity 1·06,
1 gallon of solution of pearl ashes, of the specific gravity 1·04.

These to be mixed up with a sufficient quantity of cold water to make the whole mixture amount to 22 gallons. The specific gravity of this liquor should be from 1·020 to 1·025.

This liquor has a milk-white appearance, and is in fact a kind of imperfect soap. It is put into a large wooden, open, cylindrical vessel called the *liquor tub*, and is kept constantly in motion (to prevent subsidence) by wooden levers driven round in it by machinery. This liquor is conveyed by tin pipes to a kind of trough in what is called the *padding machine*, where the cloth is thoroughly soaked in it. The longer the cloth is allowed to remain impregnated with this liquor the better does it take the dye. Fourteen days is the least period that this impregnation is allowed to remain.

The sheep dung gives the cloth a green colour, and is found materially to assist the bleaching process, to which it is afterwards subjected. It is found to increase the rapidity of the bleaching, especially when the cloth is exposed on the grass between the different operations.

4. In favourable weather, the cloth impregnated with the imperfect soap of No. 3, is spread upon the grass to dry. But in rainy weather it is dried in the stove.

5. The cloth thus dried is a second time impregnated with the oleaginous liquid of No. 3. It is then dried again.

The impregnation and drying are repeated a third time.

6. The cloth is steeped in a weak solution of pearl ash, of a specific gravity from 1·0075 to 1·01, heated to the temperature of 120°. From this liquor it is wrung out and again dried.

7. A mixture is made of the following substances :—
1 gallon Gallipoli oil,
3 gallons soda ley, of specific gravity 1·04,
diluted with as much water as make up the whole to 22 gallons. In this liquid the cloth is soaked as it was in that of No. 3.

The cloth thus impregnated is in fine weather dried on the grass, in rainy weather in the stove.

8. The process, No. 7, is repeated thrice, and after each soaking the cloth is exposed for some hours on the grass, and finally dried in the stove.

9. The cloth is steeped in a mixed ley of pearl ash and soda, of the specific gravity 1·01 to 1·0125, heated to the temperature of 120°. It is allowed to drain for some hours and then well washed. It is then dried in the stove. The object of this process is to remove any superfluous oil which might adhere to the cloth. Should any such oil be present, the succeeding process, the *galling*, could not be accomplished.

10. For the galling, 18 lbs. of Aleppo galls are to be boiled for

four or five hours in 25 gallons of water, till the bulk is reduced to about 20 gallons. This liquid, after straining, is strong enough to impregnate 100 lbs. of cloth with the requisite quantity of nutgalls. Of late years, sumach from Sicily has been substituted for nutgalls; 33 lbs. of sumach being reckoned equivalent to 18 lbs. of nutgalls. Sometimes a mixture of 9 lbs. of nutgalls, and 16½ lbs. of sumach, is employed.

In this liquor, heated to 80° or 100°, the cloth is fully soaked. The sumach gives the cloth a yellow colour, which serves to improve the madder-red, by rendering it more lively.

11. The next step is to fix the alumina on the cloth. This step is essential, because without it the madder dye would not remain, but would be washed off by water.

In this country alum is used by the manufacturers, but in many parts of the continent acetate of alumina is employed. To form the alum liquor of the Turkey-red dyers, to a solution of alum, of the specific gravity 1·04, as much pearl ash, soda or chalk is added, as is sufficient to precipitate the alumina contained in the alum. Through this muddy liquor (which should have a temperature from 100° to 120°) the cloth is passed, and steeped for 12 hours. The alumina is imbibed by the cloth, and unites to its fibres.

12. The cloth thus united with alumina is stove dried, and then washed out of the alum liquor.

13. These essential preliminary steps having been taken, the cloth is ready to receive the red dye.

From 1 to 3 lbs. of madder, reduced to the state of powder, are employed for every pound of cloth; the quantity depending upon the shade of colour wanted. The cloth is entered into the boiler while the water is cold. It is made to boil in an hour, and the boiling continues for two hours. During the whole of this time the cloth is passed through the dyeing liquor by means of the winch.

For every 25 lbs. of cloth dyed, one gallon of bullock's blood, is added. This is the quantity of cloth dyed at once in a boiler. The addition of the blood is indispensable for obtaining a fine red colour. Many attempts have been made unsuccessfully to leave it out. It seems probable that the colouring matter of blood is fixed on the cloth. Its scarlet tint would doubtless improve the colour of madder-red.

14. *Madder-brown*, by this process, is fixed on the cloth as well as madder-purple or madder-red. This gives the cloth a brownish-red and rather disagreeable colour. But the brown colour not being nearly so fixed as the red, it is got rid of altogether by the next process, which is known by the name of the *clearing* process. The cloth is boiled for 12 or 14 hours in a mixture of 5 lbs. soda, 8 lbs. soap, and from 16 to 18 gallons of the residual liquid of No. 9, with a sufficient quantity of water. By this boiling, the brown colouring matter is mostly removed, and the cloth begins to assume the fine tint which characterizes Turkey-red dyed cloth. It is still farther improved by the next process.

15. Five or six pounds of soap, and from 16 to 18 ounces of protochloride of tin in crystals, are dissolved in water in a globular boiler, into which the cloth is put. The boiler is then covered with a lid which fits close, and the boiling is conducted under the pressure of two atmospheres, or at a temperature of 250°½. The boiler is furnished with a safety valve and a small conical pipe, the extremity of which has an opening of about $\frac{3}{10}$ths of an inch in diameter, from which there issues a constant stream of steam during the operation. The salt of tin is found materially to improve the colour. Probably the oxide of tin combines with the oleaginous acid of the soap (fixed in the cloth). This insoluble soap doubtless unites with the red colouring matter of the madder, and alters the shade.

16. After all these processes, the cloth is spread out on the grass, and exposed to the sun for a few days, which finishes the clearing.

Such is a sketch of the Turkey-red dyeing, as practised in the principal works in Glasgow. Many attempts have been made to shorten these tedious processes, but hitherto without success. The impregnation with oil, or rather soap, is essential. If one, two, or three immersions be omitted, the red is inferior in proportion to these omissions. Doubtless this soap combines with, and remains attached to the cloth. And the same remark applies to common soap.

Cloth bleached by means of chlorite of lime does not produce a good red. Doubtless the fibres of the cotton wool combine with lime, or rather with sulphate of lime, which by decomposing the oleaginous soap, prevents it from combining with the cloth. But cloth bleached by the old process; namely, boiling in ley or soap and exposure to the action of the sun, answers perfectly. The colours would be as good without the galls as with them. But there would be considerable difficulty in sufficiently impregnating the cloth with the alum liquor, without its being previously passed through the gall decoction, especially if the cloth be in the least degree greasy.

SECTION II.—OF ARCHIL AND CUDBEAR.

Archil, distinguished in France by the name of *orseille*, is a dye-stuff prepared originally from the *parmelia roccella*, a lichen which is found in the countries bordering on the Mediterranean; but the finest quality came from the Canary Islands, which, however, have been so long resorted to for that peculiar lichen, that it has now become so scarce and so high-priced, that these islands no longer furnish the requisite supply. If we believe Tournefort, the use of this lichen, as a dye-stuff, was known to the ancients. It was the substance employed in dyeing what was called the *purple of Amorgos*, one of the Cyclades, where tunics, celebrated for their colour were dyed, and sold under the name of *amorgis*. Tournefort informs us that when he was in the island the lichen was still collected, and sold for ten crowns the hundred weight.*

* Tournefort's Voyage, i. 248. English Translation.

After the extinction of the Roman empire, the method of dyeing by means of this lichen was lost. But about the beginning of the fourteenth century, a Florentine, named Federigo, discovered accidentally the tinging properties of this lichen while in the Levant. He established a manufactory of archil in Florence, and realised so large a fortune, that he became the chief of one of the first families in Florence. They took the name of Oricellarii (from the dye-stuff), which was gradually changed into Rucellarii and Rucellai. For more than a century Italy possessed the exclusive manufactory of archil. The lichen employed was collected on the shores of the islands in the Mediterranean. When the Canary Islands were discovered, in 1402, the lichen was collected in them, and more lately in the Cape Verde Islands. The lichens from these islands furnished a greater quantity of colouring matter than those in the Mediterranean, because they had reached their full growth.

Of late years the parmelia roccella has become scarce and high-priced in the Canary and Cape Verde Islands. Hence the supply is brought from other places; and there cannot be a doubt that various other lichens are employed in the preparation of archil.

Berthollet, who has copied Hellot, who again copied Micheli, has given the following description of the mode of preparing it:—

The plant is reduced to a fine powder, which is afterwards passed through a sieve, and slightly moistened with stale urine. The mixture is daily stirred, each time adding a certain quantity of soda in powder, till it acquires a clove colour. It is then put into a wooden cask, and urine, lime water, or a solution of sulphate of lime (gypsum) is added in sufficient quantity to cover the mixture. In this state it is kept; but to preserve it any length of time, it is necessary to moisten it occasionally with urine. I have never had an opportunity of seeing the mode of preparing archil, but from my knowledge of the mode of making cudbear, which is an analogous dye-stuff, I suspect that the above description of Micheli is not accurate.

What is called in this country *cudbear*, and in Germany *persio*, is prepared from the *leconora tartarea* and *parmelia omphalodes*, by a process which is, doubtless, similar to that employed for making archil. The lichen is steeped, and left for some time in flat vessels, moistened with the liquid ammonia. This ammonia was at first obtained from putrid urine by distillation. But it is now procured by distilling the aqueous liquor which is obtained during the process of manufacturing coal gas for lighting the streets. When the purple colour is sufficiently developed the whole is dried in the open air, and reduced to a fine powder. This manufacture was begun at Leith, about the year 1777, by the late Mr Macintosh of Glasgow. The manufacture was first started at Leith, under the management of Dr Cuthbert Gordon. It was from this gentleman's name that the term *cudbear* (at first *Cuthbert*) originated. Leith was found an improper place for the manufacture. Mr Macintosh, therefore, transferred it to Glasgow, where it is still carried on by

Charles Macintosh, Esq., of Campsie, son of the original proprietor. The lichens used were at first collected in the Highlands of Scotland. But the rocks of that country being stript of their covering, the manufacturers had recourse to Sweden and Norway, and likewise to Sardinia, from which countries prodigious quantities of the lichen were brought.

Neither archil nor cudbear are capable of giving fast colours to cloth; but they are considered as indispensable by the dyers, because they greatly improve the brilliancy of some of the colours.

The nature of the substance in the parmelia roccella, which furnishes the colouring matter of archil, has been investigated by M. Heeren, who has distinguished it by the name of *erythrin*. He procured it in the following manner:—

He digested the lichen for some time in alcohol, taking care not to raise the temperature of the liquid to the boiling point, because at that temperature a portion of the erythrin is decomposed. The alcoholic solution, which had a green colour, was filtered while hot, and mixed with twice its bulk of water, which rendered it muddy. The temperature of the liquid was raised to the boiling point, and chalk was added to it till the precipitate at first dispersed through the liquid collected in flocks. The precipitate consisted chiefly of *roccellate of lime*. The liquid thus freed from roccellic acid was filtered while boiling-hot. During the cooling it deposited impure erythrin in the form of a fine powder, having a brown colour. This precipitate was dissolved in hot alcohol, and the solution was digested with ivory-black, filtered, and mixed with $1\frac{1}{2}$ times its bulk of boiling water. At first the liquid remained clear, but during the cooling the erythrin was deposited nearly white.

M. Heeren has given another process for extracting erythrin from the lichens, which is of easier execution. It is as follows:—Pour on the lichen a small quantity of concentrated ammonia, and digest for some time, but without the application of heat. Dilute the muddy and reddish solution thus obtained with water, and then add some dilute solution of chloride of calcium. Roccellate of lime precipitates, and the filtered liquid has a reddish colour. Add to it a slight excess of muriatic acid. The erythrin instantly precipitates, and gives to the liquid the aspect of a yellowish jelly. When we heat to the boiling temperature the erythrin is again dissolved, and it is precipitated in powder during the cooling of the liquid. It may be deprived of its brown colour by ivory-black.

Erythrin is a soft powder, having usually a shade of red, and a slightly crystalline aspect when obtained from a weakly acid liquor. When pure it is perfectly white, and is destitute both of taste and smell. At a temperature a little above 212° it melts into a transparent liquid, which becomes hard and brittle on cooling. If the heat be raised still higher it froths, is partly volatilized, and partly charred, but not the least trace of ammonia can be observed. Hence we may conclude that erythrin contains no azote. When held to the flame of a candle it burns like a resin.

It is scarcely soluble in cold water, and requires 170 times its weight of boiling water to dissolve it. At the temperature of 53° it dissolves in 22½ times its weight of alcohol, of the specific gravity 0·825. It is soluble in 2·29 times its weight of the same alcohol, at the ebullition. When this last solution cools the whole assumes the form of a mass of the consistency of mortar. It is insoluble in ether, and but little soluble in oil of turpentine. Muriatic acid has no action on it, but acetic acid dissolves it with facility when boiling-hot, but lets it fall again on cooling. Both nitric acid and concentrated sulphuric acid dissolve it, but they alter its nature. The aqueous solutions of the alkalies or their carbonates dissolve it with facility, and the solutions are colourless. By the continued action of the alkalies the erythrin is decomposed. When this action takes place in close vessels an extractive substance is formed, which is soluble in water, has a bitter taste, and which Heeren on that account calls *bitter of erythrin*. When the action is continued in vessels to which the air has access, the red, or rather violet, substance is formed, which constitutes the colouring matter of archil.

During the conversion of erythrin into the red colouring matter, three different substances are obtained, namely, the *red colouring matter*, a *yellow* substance, and a *wine-red* substance. They are at first mixed or combined. But the red colouring matter may be separated by dissolving the compound substance in alcohol, evaporating the solution to dryness, and digesting the residue in ammonia. When the ammoniacal solution is evaporated the red colouring matter remains.

It is little soluble in water. Alcohol dissolves it, and the solution has a crimson-red colour. It is quite insoluble in ether. The alkalies and their carbonates dissolve it, and the solution has a fine deep-violet colour. The acids throw it down from these solutions under the form of a carmine-red powder; but they do not precipitate it from its solution in alcohol, only rendering the colour more clear.

The *yellow substance* has been but slightly examined. It dissolves in alcohol, but is insoluble in water and ammonia. It is easily decomposed by the action of heat. Hence when we heat a mixture of the yellow and red matter of the lichen, we may destroy the yellow without altering the red substance.

The *wine-red substance* which remains in solution in the carbonate of ammonia when we precipitate the combination of the lichen red and yellow matter, does not alter its colour by exposure to the air; nor is it changed into the red colouring matter by the continued and simultaneous action of air and ammonia. But when we evaporate the liquid, and heat the residual matter till it be brought into a state of semifusion, it exhales a vapour having a peculiar, but non-ammoniacal odour, and assumes suddenly a deep and pure red colour. It is then converted into red colouring matter. This change is the result of a decomposition, and not of

oxidizement: for it takes place equally under olive oil or on mercury.

When we digest the parmelia roccella in boiling alcohol, and treat the alcoholic solution as if we were going to prepare erythrin, the liquid filtered boiling-hot, after being mixed with chalk, deposits, after some hours, a slimy sediment. If we heat this deposit with a small quantity of the liquid it dissolves almost completely, and is deposited again during the cooling of the liquid (which must be filtered while hot) under the form of fine brown crystals, which may be whitened by digestion in alcohol with animal charcoal. This substance is the result of the action of boiling alcohol on erythrin, and seems to come in place of the bitter of erythrin, for it is impossible to transform it into that substance. Heeren has distinguished it by the name of *pseudo-erythrin*.

It is snow-white, and has the form of scales or flat needles, sometimes an inch and half long. It is little soluble in water. Alcohol dissolves about a fifth of its weight of it at 32°. It melts when heated a little above 148°, and while in fusion resembles a colourless oil. On becoming solid it assumes the form of crystalline scales. With acids and alkalies it exhibits the same phenomena as erythrin, with this difference, that it does not yield any *bitter principle;* and that when exposed to the joint action of ammonia and air, it is very slowly converted into the *wine-red liquor*.

According to Liebig, its constituents are:—

Carbon	60·00 or 20	atoms =	15	or per cent.	61·07
Hydrogen	6·33 or 12½	atoms =	1·5625	— —	6·36
Oxygen	33·67 or 8	atoms =	8·00	— —	32·57
	100·00*		24·5625		100·00

It appears from the observations of Robiquet,† that the *variolaria dealbata* is frequently employed in France in the manufacture of archil. This induced him to subject that lichen to an elaborate analysis, the result of which may be stated as follows:—

The lichen was dried and pulverized, and digested in boiling alcohol successively, till every thing soluble in that menstruum was taken up. The alcoholic solutions filtered while hot let fall, on cooling, crystalline flocks, which have no connection with the colouring matter of the lichen. The alcohol was distilled off till the residual liquid was reduced to the consistence of an extract, which was triturated in a mortar with water, as long as that liquid continues to dissolve any thing. The aqueous solution, being reduced to the consistence of a syrup and left to itself in a cool place, let fall, after an interval of some days, long brown brittle needles. These were freed by pressure from the mother water, redissolved in water, digested with ivory-black, and crystallized a second time. The new-formed crystals had a yellow colour.

They may be rendered still purer by redissolving them in water,

* Poggendorf's Annalen, xxi. 33.

† Ann. de Chim. et de Phys. xlii. 236.

precipitating the solution by means of diacetate of lead, washing the precipitate, diffusing it in water, and throwing down the lead by a current of sulphuretted hydrogen. The filtered liquid now yields colourless crystals, which have the shape of flat four-sided prisms terminated by a bihedral summit. This is the substance which furnishes the colouring matter of archil, and which Robiquet has distinguished by the name of *orcin*.

Its taste is sweet, and at the same time disagreeable. When heated it melts into a transparent liquid, which may be distilled over unaltered. It is soluble both in water and alcohol. Nitric acid causes it to assume a blood-red colour; if we continue the action this colour disappears, but no oxalic acid is formed. Diacetate of lead precipitates it completely from its solution.

But the characteristic property of orcin is, that when exposed to the joint action of ammonia and air, it becomes of a deep-violet colour. To obtain this colour in its most beautiful state, certain precautions are necessary. When digested with potash or soda, and exposed to the air, it becomes of a reddish-brown colour. If we dissolve it in ammonia and then expose it to the air, the colour which it acquires is not so dark, yet it is not beautiful. But if we expose it to the action of air loaded with ammoniacal fumes, it acquires by degrees a violet colour. To obtain it in this state, the orcin, in fine powder, is put into a capsule, beside another open vessel containing ammonia, placed in a water or mercurial trough, and the two are covered by a class jar. As soon as the orcin has become dark-brown it is removed from below the jar, and the excess of ammonia which it has imbibed is allowed to exhale. As soon as it has lost its ammoniacal smell it is dissolved in water. When a few drops of ammonia are added to this solution it assumes a beautiful reddish-violet colour. Acetic acid precipitates the red colouring matter of the lichen from this solution. Sulphuretted hydrogen deprives it of its colour; but the colour appears again if we saturate the sulphuretted hydrogen with an alkali.

To the substance into which orcin is converted by the joint action of oxygen, ammonia, and water, Robiquet has given the name of *orcein*. He considers it as orcin united not with ammonia, but with the elements of that alkali, and indebted to these elements for its colouring powers. The oxygen seems only to commence the combination, and the moisture is necessary merely to enable the ammonia to act upon the *orcein*. Orcein is but little soluble in water, but dissolves readily in the alkaline leys.*

Robiquet conjectures that the origin of the other colouring matters may be similar to that of *orcein*. Thus indigo in the leaves of plants is probably a colourless soluble substance, which becomes coloured and insoluble by combining with the elements of ammonia.

When the alcoholic decoction of the lichen is evaporated to dryness, and the residue treated with water, it yields *orcin*. When the

* Ann. de Chim. et de Phys. lviii. 320.

residual matter is digested in ether, that liquid dissolves another substance, to which Robiquet has given the name of *variolin*. This substance possesses the following properties :—

It crystallizes in white needles. When heated it melts ; and if the heat be increased a portion of the variolin may be volatilized unaltered, while another portion is converted into an essential oil. It is very soluble in alcohol and ether. It produces no change upon vegetable colours. When treated with acids or alkalies no colouring matter is produced, not even when the action is assisted by the presence of oxygen gas.

According to the analysis of Robiquet, orcin is composed of

Carbon	67·64 or 18 atoms =	13·5	or per cent. 67·93
Hydrogen	6·83 or 11 atoms =	1·375	— — 6·91
Oxygen	25·53 or 5 atoms =	5	— — 25·16
	100*	19·875	100·00

Thus its composition has no analogy to that of alizarin.

SECTION III.—OF SAFFLOWER.

Carthamus tinctorius is an annual plant, cultivated in Egypt, and the countries surrounding the Mediterranean, for the sake of its flowers, which yield an extremely beautiful, but fugitive red colour. When the flowers have come to maturity they are pulled, their juice expressed, the residue washed repeatedly with salt water, and exposed on mats to dry. Care is taken to cover them from the action of the sun during the day, and to expose them to the evening dews, in order to prevent them from drying too fast.

Beckmann published a very elaborate paper upon the flowers of the carthamus in 1774.† Dufour gave an excellent analysis of these flowers in 1804,‡ and his observations were soon after confirmed by those of Marchais.§

The flowers of the carthamus contain two colouring matters ; the first, which is soluble in water, is yellow ; the other, which has a beautiful red colour, has been called *carthamin*. This last substance Dobereiner considers as an acid, to which he has given the name of *carthamic acid*.

The yellow colouring matter dissolves readily in water ; but it is difficult to separate the whole of it by that liquid. According to Dobereiner it is proper to add a little vinegar to the water used for washing the flowers of the carthamus, especially if the water contains lime, in order to prevent the red colouring matter from being dissolved along with the yellow.

The method followed by Dufour was to put the carthamus in a linen cloth and knead it continually between the fingers, while a streamlet of water dropped upon it. By continuing this process, and then steeping the carthamus in water, it assumed a fine red

* Jour. de Pharmacie, xxi. 393.
† In the Gottingen Transactions for that year.
‡ Ann. de Chim. et de Phys. xlviii. 283. § Ibid. l. 73.

colour. The liquid which passed, after being filtered to separate some portion of the carthamus and some impurities with which it was mixed, had a yellow colour. When heated to about 145°, a number of flocks appeared in it consisting of gluten, or rather of albumen. These were separated by the filter, and the liquid evaporated to dryness. The extract obtained had a yellow colour and a strong taste. Water dissolves it with the exception of a brown matter, which possessed the characters of a resin. The watery solution reddened vegetable blues, and was precipitated abundantly by infusion of nutgalls, but not by glue. Chlorine destroyed the yellow colour, rendering the pigment white. When the solution was evaporated to dryness and treated with alcohol it was only partially dissolved. This yellow colouring matter amounted to about 27 per cent. of the weight of the dried safflower.

The carthamin, which still remains in the flowers of the carthamus treated as above described, may be dissolved by digesting the flowers in an alkaline carbonate, from which it is again precipitated by an acid. A vegetable acid, lemon juice for example, has been found to produce the best colour. Next to this, sulphuric acid produces the best effect, provided too great a quantity be not employed, which would alter or destroy the colouring matter. The juice of the berries of the *mountain ash* (*sorbus aucuparia*, Linn.) is recommended by Scheffer as a substitute for lemon juice; and it is thus prepared:—The berries are bruised in a mortar with a wooden pestil, and the expressed juice, after having been allowed to ferment, is bottled up for use. The clear portion, which is most acid, becomes fitter for use the longer it is kept; but this operation requires a period of some months, and can only be conducted in summer.

From carthamin, extracted by an alkali, and precipitated by an acid, is prepared the pigment called *rouge*, which is employed as a paint for the skin. The solution of carthamus is prepared with crystals of carbonate of soda, and precipitated by lemon juice which has stood some days to settle. After being dried on stoneware plates in a gentle heat, the carthamin is ground accurately with talc previously reduced to a very subtle powder. On the fineness of the talc depends the difference between the cheaper and dearer kinds of *rouge*.

Carthamin, when properly prepared, has a fine red colour. It reddens vegetable blues while moist, whether from the acid employed to throw it down, or from its own acid properties has not been determined. It is insoluble in water and in dilute acids, but slightly soluble in alcohol. The solution has a rose-red colour, but when boiled it becomes yellow. Ether is still a worse solvent of it than alcohol. It is insoluble in oils, both volatile and fixed; but it dissolves readily and with a yellow colour in alkalies or their carbonates. According to Dobereiner, soda saturated with it crystallizes in fine colourless needles having a silky lustre, and becoming instantly red when an acid is added.

As a dye-stuff carthamin affords only a fugitive colour, very

beautiful; but destroyed by exposure to the sun, and removed by washing. It is used, however, occasionally, to give a red colour to silk. The method is to make a cold solution of the red colouring matter in carbonate of potash or soda. The liquid is immediately filtered, and as much lemon juice being added as is requisite to throw down the carthamin, the silk cloth is passed through the liquid in the usual way by the winch. As soon as it has acquired the requisite shade of colour it is washed and dried.

SECTION IV.—OF LOGWOOD.

Logwood is the wood of the *Hæmatoxylon Campeachianum*, a tree which grows to a considerable size in Jamaica, and on the eastern shore of the bay of Campeachy. Its specific gravity is higher than that of water; it has a fine grain and is susceptible of a fine polish. Besides the colouring matter discovered by Chevreul, and distinguished by the name of *hæmatin*, it contains resin and oil, acetic acid and salts of potash, and lime combined with a vegetable acid. It contains also sulphate of lime, a little alumina, some peroxide of iron and oxide of manganese. The hæmatin is sometimes so abundant as to exist in the wood in large red crystals. A specimen of logwood, containing such crystals, was exhibited at Dublin in 1835, to the Chemical Section of the British Scientific Association, by Mr Scanlan.

Chevreul made a chemical examination of logwood in 1812.* He has given us the following method of extracting hæmatin from it:

The raspings of the wood are digested in water of a temperature between 122° and 131°, till every thing soluble be taken up. Evaporate the aqueous solution to dryness by a gentle heat, and treat the residue with alcohol of the specific gravity 0·843, which will leave undissolved a brown residue still containing hæmatin in combination. Filter the alcoholic solution, and distil it till what remains becomes of the consistence of a syrup. This syrup being mixed with some water, crystals begin immediately to be deposited. Leave it for 24 hours to evaporate spontaneously, then decant the liquid portion from off the crystals and wash them with a little alcohol. The decanted liquid being left to spontaneous evaporation will yield more crystals, and finally remains a thick uncrystallizable liquid. If we evaporate this liquid to dryness, macerate the dry residue in cold water and evaporate afresh, more crystals are obtained, which may be purified like the others by washing them in alcohol. These crystals constitute *hæmatin*, or the colouring matter of logwood.

They have considerable lustre, and a scarlet colour. Under the microscope they assume the appearance of needles arranged in sphericles. A glass coated with hæmatin appears orange by transmitted, and white by reflected light. When put into the mouth it is at first tasteless; but after a certain time a sensation of astrin-

* Ann. de Chim. lxxxi. 128.

gency, acridity, and bitterness is perceived. When heated in a retort till it is decomposed it gives out ammonia, showing that it contains azote as one of its constituents. The charry matter remaining (after every thing volatile has been driven off) amounts to 54 per cent., which, when burnt in the open air, leaves a residue consisting of lime and peroxide of iron, amounting to rather less than 1 per cent. of the hæmatin employed.

Hæmatin requires, to dissolve it, 1000 times its weight of water. The solution, when evaporated, does not yield crystals; but when very much concentrated, it is converted into a confused crystalline mass. It dissolves in alcohol and ether, and the solutions have a reddish-yellow colour. It combines with the acids, which render it yellow when added in small quantity; but when in larger proportion, they give it a red colour. Arsenious acid has no sensible action on it. Sulphuretted hydrogen gas renders it yellow; and if we keep a solution of hæmatin, charged with this gas (for some time), in a corked phial, it loses its colour altogether. But the colour reappears, if we remove the gas by a little oxide of lead. The alkalifiable bases give a solution of hæmatin a violet, purple, or blue colour. With the fixed alkalies it forms blue compounds, perfectly saturated and soluble, provided atmospherical air be excluded. The alkaline earths precipitate in combination with it, and have a purple colour when from neutral salts, and a blue colour when from subsalts. An excess of alkali destroys the colour altogether. With the hydrated oxides of antimony, zinc, bismuth, nickel, iron, and copper, it forms blue or purple-coloured compounds. The compound which hæmatin forms with alumina and oxide of copper, may be fixed upon linen or cotton, and gives a blue colour like that of indigo; only it is rendered yellow by the concentrated acids, while indigo remains unchanged, unless the acid be the nitric. The protoxide of tin, when united with hæmatin, forms a blue coloured compound, while its compound with peroxide of tin is red. A solution of gelatin throws down a concentrated solution of hæmatin purple.

Boracic acid has this remarkable action on hæmatin, that how small soever the quantity employed, provided it be sufficient to produce a sensible effect, it develops a purple-red; that is to say, the boracic acid acts as an alkali rather than an acid. The addition of a little sulphuric acid changes the red from boracic acid into yellow. Boiling nitric acid decomposes hæmatin, and oxalic acid is formed. Chlorine also decomposes it very rapidly.

Hæmatin is easily altered. When a mixture of alkali and hæmatin is kept *in vacuo*, or in a well corked phial, quite full, no action takes place; but when air has access, oxygen is absorbed, and the hæmatin quite destroyed in a few hours. During this action, the blue colour of the liquid changes first into red, and then into brown. The alkali becomes saturated with carbonic acid.

Logwood is chiefly employed by the calico-printer, to give cotton a black or a brown colour. The cloth is always, in the first place, impregnated with the alum mordant. If it be now dyed in a de-

coction of logwood, it becomes *black*. Iron mordant and logwood also make a black; but the shade of brown which it in that case has, is less pleasing to the eye. If cloth, impregnated with the alum mordant, be dyed in a mixture of logwood and madder, a very fine brown colour is fixed upon it.

SECTION V.—OF BRAZIL-WOOD.

Brazil-wood comes to this country both from Brazil and Pernambuco. That from Brazil is said to be the wood of *cæsalpina sapan, cæsalpina crista, and cæsalpina vesica;* while that from Pernambuco is the wood of the *cæsalpina echinata*. These trees are large and rich in a colouring matter, which Chevreul has distinguished by the name *brezilin*. The wood is very hard, and is said to sink in water. When fresh cut, it is pale; but assumes a red colour when exposed to the air. Its taste is sweetish. The red colouring matter of this wood is rendered *yellow* by acids, and *violet* by alkalies.

Chevreul* has given us the following process for extracting *brezilin* from this wood, in a state approaching to purity:—

Digest the raspings of the wood in water till all the colouring matter is dissolved, and evaporate the infusion to dryness, to get rid of a little acetic acid which it contains. Dissolve the residue in water, and agitate the solution with litharge, to get rid of a little fixed acid which it contains. Evaporate again to dryness. Digest the residue in alcohol: filter and evaporate, to drive off the alcohol. Dilute the residual matter with water, and add to the liquid a solution of glue, till all the tannin which it contains is thrown down. Filter again, evaporate to dryness, and digest the dry residue in alcohol, which will leave undissolved any excess of glue that may have been added. This last alcoholic solution being evaporated to dryness, leaves brezilin in a state of tolerable purity.

Brezilin is soluble both in water and alcohol. Its fine red colour does not appear till all the acid which it naturally contains is saturated. Acids give it a yellow colour. The sulphuric, nitric, and muriatic acids give it a pale dirty yellow. Fluoric acid converts it at first to yellow, which is gradually altered to greyish-green; while the phosphoric and citric acids give it a fine permanent yellow colour, which might be employed for dyeing silk and wool. For these facts we are indebted to Bonsdorf.

A very minute quantity of alkali gives the infusion of Brazil-wood a violet colour: it is therefore a delicate reagent for alkalies. When neutral salts, with an alkaline base, are dissolved in the infusion of Brazil-wood, it assumes a rose-red colour. Acetates act most decidedly in producing this effect. When newly precipitated alumina is agitated in this infusion, it assumes a carmine-red colour.

When Brazil-wood is boiled in water, we obtain a rose coloured solution, and the undissolved wood becomes black, but still yields to alcohol a dark red colour. When an acid is poured into the de-

* Ann. de Chim. lxvi. 225.

coction, a red precipitate falls, and the filtered liquid is yellow. Ammonia gives the decoction a purple colour, and throws down a purple precipitate. The carbonates of potash and soda render it carmine-red, and throw down a precipitate of the same colour. Alum throws down an abundant carmine precipitate; but the liquid retains the same colour. The protochloride of tin gives a rose-red precipitate, and renders the decoction colourless. Brazil-wood is the substance from which red ink is made. The colour which it communicates to cloth has very little permanence. Yet it is occasionally employed in giving cotton what are technically called *chemical colours*, by which is understood colours which will not resist washing. The decoction of Brazil-wood, which is called *juice of Brazil*, is found to answer better for the process of dyeing when it has been kept for some time, and has even undergone some degree of fermentation, than when it has been fresh prepared. The colour, by keeping, becomes yellowish-red.

Within the last ten years, Brazil-wood has been nearly superseded by a wood imported from Africa, to which our dyers give the name of *camwood*. It is richer, and gives a finer colour than any of the varieties of Brazil-wood. It is not so much affected by alkalies, nor so liable to assume a violet shade; and the yellow colouring matter with which it is mixed gives the red a more lively appearance.

The tree which yields this wood grows in Sierra Leone and the interior of Africa. It reaches the height of about 60 feet. It was first noticed by Afzelius, and is figured in *Loddige's Botanical Cabinet* (iv. 367), under the name of *Baphia nitida*.

SECTION VI.—OF RED SANDERS.

Red sanders is the name given in this country to the wood of the *pterocarpus santalinus*, a large tree which grows upon the Coromandel coast and other parts of India, especially Ceylon. Old wood only is employed as a dye-stuff, young wood containing very little colouring matter. This wood is at first light-red, but becomes very dark by exposure to the air. It is very compact and ponderous, and has no smell, and very little taste. The colouring matter which it contains was examined by Pelletier* in 1814, who distinguished it by the name of *santalin*.

It is easily obtained by digesting the rasped wood in alcohol, and diluting the alcoholic solution with water, after it has been filtered. The santalin gradually precipitates in the state of a fine powder, having a beautiful carmine colour. We may obtain santalin also, by digesting the wood in caustic ammonia, which dissolves the colouring matter, and saturating the alkali with muriatic acid. The santalin precipitates.

Santalin is tasteless, and almost insoluble in water, 1000 parts of water dissolving only 1·6 part of it, but it dissolves readily in

* Jour. de Phys. lxxix. 268.

alcohol, in all proportions—a weak solution having a yellow and a strong one a red colour. It is soluble in ether, and the solution has a red colour. Acetic acid dissolves it, and acquires a red colour. This solution has an astringent taste. Water renders it muddy. It is precipitated by gelatin.

1000 parts of boiling oil of turpentine, dissolve $6\frac{1}{2}$ parts of santalin; while 1000 parts of boiling oil of lavender dissolve 20 parts of it. Solutions of potash, soda, and ammonia dissolve it, and assume a red colour. The santalin may be precipitated unaltered from these solutions by means of an acid. Yet the liquids remain yellow, and when viewed by reflected light they are blue.

When chloride of tin is dropt into the alcoholic solution, a beautiful purple lake precipitates. The following effects of reagents were also observed by Pelletier :—

Acetate of lead, a violet precipitate.
Corrosive sublimate, a scarlet do.
Sulphate of iron, a deep violet.
Nitrate of silver, a reddish-brown.
Salts of alumina, no precipitate,

except that occasioned by the water in which they are dissolved.

Sulphuric acid blackens and destroys santalin. Nitric acid alters it even cold. Oxalic acid is formed, together with a yellow bitter substance, soluble in water, and a yellow resinous substance. When distilled, it yields a little empyreumatic oil, but no ammonia. Its constituents, determined by the analysis of Pelletier,* are

Carbon	75·03 or	16 atoms =	12	or per cent.	75
Hydrogen	6·37 or	8 atoms =	1	— —	6·25
Oxygen	18·6 or	3 atoms =	3·00	— —	18·75
	100·00		16		100·00

Red sanders is very little used in this country as a dye-stuff; but apothecaries often employ it to give a red colour to tinctures. In India it is used both for dyeing silk and cotton. Dr Bancroft obtained a fixed and beautiful yellowish-red on woollen cloth, by first passing the cloth through a mixture of alum and tartar, and then dyeing it with a mixture of red sanders and sumach. When chloride of tin is employed as a mordant it dyes a fine brownish-red; with alum it forms a scarlet-red, and with sulphate of zinc, a deep crimson. But in general the colours communicated by red sanders are not considered as very fixed.

SECTION VII.—OF CACTIN.

Vogel has obtained 30 per cent. of matter, having a carmine-red colour, from the flowers of the *cactus speciosus*, by means of weak alcohol. This colouring matter is insoluble in ether and absolute alcohol. After having treated the petals with alcohol, a mixture of ether and alcohol extracts between 5 and 10 per cent. of a scarlet

* Ann. de Chim. et de Phys. li. 192.

coloured matter. Both of these colouring matters are soluble in water.*

SECTION VIII.—OF RED FLOWERS.

The petals of many flowers have a very intense red colour, frequently produced by so small a quantity of colouring matter, that it disappears altogether when we attempt to extract it. We find it in general situated in the epidermis of the petals; the juice obtained by subjecting the petals to pressure being generally colourless. The colouring matter of deep red flowers is often rendered blue by an alkali, and yellow or red by acids—in this respect resembling hæmatin. The colour of the petals of the *papaver rhœas* is a lively red. Potash changes it to *green*, but the carbonates of soda and ammonia are said not to alter it. The infusion of these petals in carbonate of soda or of ammonia is red; but it becomes green on the addition of potash.

Some observations upon red flowers were made in the third Section of the preceding Division. And so little attention has been paid to the subject by modern chemists, that I have no farther remarks to add to the few facts which were there stated, chiefly on the authority of Mr Smithson.

DIVISION III.—OF YELLOW COLOURING MATTERS.

Probably the yellow colouring matters in the vegetable kingdom are more numerous than either the blue or the red. But those only can be introduced here which have attracted the notice of chemists, or at least of artists, in consequence of their being employed as dye-stuffs. Unfortunately they have been much less studied than either blue or red colouring matters. Of course our knowledge of them is much more imperfect.

SECTION I.—OF QUERCITRON BARK.

The dye-stuff called *quercitron*, is the inner bark of the *quercus nigra*, a large tree which grows sponstaneously in North America, and which has been introduced both into France and Bavaria. Its dyeing properties were first made known to the public by Dr Bancroft in 1784. An act of parliament was passed in his favour in 1786, vesting in him exclusively the use and application of it as a dye-stuff for a certain term of years. To prepare it for use, the epidermis is taken off, and the inner bark pounded in a mill. The result is a powder of a light yellow colour. It contains a good deal of tannin, and a yellow colouring matter, to which Chevreul has given the name of *quercitrin*.

When we concentrate slowly an infusion or decoction of quercitron bark, a crystalline matter is deposited, which has a pearly lustre while suspended in the liquid. This is *quercitrin*.

* Jour. de Pharmacie, xxii. 664.

It is composed of small plates or scales, which, when examined before the microscope, have the crystalline aspect of mosaic gold; but their colour is yellow, inclining a little to grey. It dissolves in small quantity only in water; the solution has a pale yellow colour, and is not precipitated by solution of isinglass. It is very little soluble in ether; but more so in alcohol. When dissolved in potash or ammonia, it assumes a greenish-yellow colour. Barytes water slowly precipitates it in yellow flocks. Solution of alum strikes with it a beautiful yellow colour, but no precipitate falls, even after an interval of three hours. It is precipitated in yellow flocks by acetate of lead, chloride of tin, and acetate of copper. Sulphate of copper causes it to assume an olive green colour, with a shade of brown, and a precipitate subsides very slowly.

Nitric acid of the specific gravity 1·300 causes it to assume an orange-red colour. Sulphuric acid dissolves it; the solution has an orange-yellow colour, with a shade of green. Water added to the liquid occasions a precipitate.

When cloth previously impregnated with the alum mordant is passed through an aqueous solution of quercitrin, it is dyed yellow, rather of a paler shade than that given by *morus tinctoria*, or *old fustic*, as it is called by our dyers. It dyes silk, previously impregnated with the iron mordant, olive green, having a shade of grey.

When quercitrin is heated in a large retort, it gives off moisture, then melts, becomes brown, disengages a yellow vapour, two different varieties of oil, and gaseous matter. A light charry matter remains behind. The liquid that comes over yields yellow crystals, which are soluble in water, alcohol, and ether, to which they communicate their own colour. These crystals dye precisely like quercitrin, and doubtless are of the same nature.*

SECTION II.—OF OLD FUSTIC.

This very improper term is applied by the British dyers to the wood of the *morus tinctoria*, a large tree which grows wild in Brazil, Jamaica, and most of the West Indian islands. We do not know when it was introduced as a dye-stuff; but Pomet, in his work on drugs, printed in the year 1692, mentions it under the name of *bois jaune* (the name by which the French designate this dye-stuff), a wood which he says was employed in England to dye yellow; though he was unacquainted with its origin. The colour of this wood is sulphur-yellow; its price is moderate, and it readily combines with indigo, which properties give it a claim to attention as a valuable ingredient in dyeing.

The origin of the term *fustic*, applied to this colouring matter in Great Britain, is not very well understood. The French applied the term *fustet* to the *rhus cotinus*, or *Venice sumach*, which yields a fugitive and bad yellow. Dr Bancroft supposes that *fustic* is merely a corruption of the word *fustet*. When the morus tinctoria was in-

* Chevreul, Leçons de Chimie Appliquée à la Teincture, ii. 30 Leçon, p. 163.

troduced, being the wood of a large tree, it was called, he supposes, *old fustic*, while the *rhus cotinus*, being only a shrub, was called *young fustic*.*

Before fustic can be employed as a dye-stuff, it must be cut into chips and put into a bag, that it may not fix in and tear the cloth to which it is to impart its colouring matter. When fustic is boiled in water, it imparts its colouring matter to that liquid. Now, if we concentrate the decoction, and allow it to cool, we obtain a matter which seems to have crystallized confusedly. Its colour is yellow, though occasionally it may present portions which have a red or orange shade. This substance was examined by Chevreul in 1818,† and described by him under the name of *morin*.‡

It is but little soluble in water, even at a boiling temperature. A boiling solution, when allowed to cool, deposits flocks, which, when dried on the filter, have a crystallized appearance. The solution is light yellow. It is more soluble in alcohol than in water; and when the solution is left to spontaneous evaporation, the morin is deposited in crystals. It is still more soluble in ether than in alcohol. The ethereal solution, when left to spontaneous evaporation, deposits yellow needles arranged in the form of a star.

The aqueous solution of morin is precipitated by gelatin. Potash, ammonia, barytes, strontian, and lime, give it a fine yellow colour, without occasioning any precipitate. A solution of alum gives it a greenish-yellow colour. Sulphated peroxide of iron causes a precipitate, and strikes a green colour with it. Sulphuric acid dissolves it, and forms an orange-yellow solution, with a tint of green. Nitric acid, when boiled with it, converts it into oxalic acid.

When the aqueous solution of morin is exposed to the air, it imbibes oxygen, and assumes a red colour. This change does not take place if oxygen gas be excluded. When morin is heated in a retort it melts, assumes a reddish-brown colour, gives out water, and a liquid which crystallizes, on cooling, in yellow needles. It gives out likewise oil and gas, and a light charcoal remains behind. The yellow crystals strike a green instantly with sulphated peroxide of iron.

When we examine the wood of the morus tinctoria, we often perceive in it a pulverulent matter, either yellow or flesh-red. This matter, according to Chevreul, is almost entirely composed of morin, as may be ascertained by treating it with ether, which dissolves it and deposits it in crystals. When the flesh-red powder is digested in ether, it leaves a red matter undissolved, to which it was indebted for its red colour. The ethereal solution is yellow, with a shade of green. When evaporated it leaves crystals less coloured than those of morin; and if the ether has been applied in successive portions, those of the second washing are less yellow

* Bancroft on Permanent Colours, i. 412. † Ann. de Chim. et de Phys. ix. 330.
‡ Leçons de Chimie appliquée à la Teincture, ii. Leçon 30, p. 152.

than those of the first. If we wash the yellow crystals on a filter with water they become nearly white. To these crystals Chevreul has given the name of *white morin.*

It has a sweetish taste; but at the same time leaves an impression of astringency and bitterness. It has little action on gelatin. The alkalies give it a deeper yellow colour. Barytes occasions no precipitate in it. It instantly precipitates acetate of copper in yellow flocks. Morin only causes it to precipitate after a considerable interval of time. When mixed with sulphated peroxide of iron, it becomes garnet-red, whereas the solution of morin becomes green. Concentrated sulphuric acid makes the solution pass to rust-yellow, while it changes morin into a brilliant yellow.

Both morin and white morin act as colouring matters. White morin gives a greenish-yellow, and morin a yellow with hardly a perceptible tint of green. Silk, impregnated with the iron mordant, when dyed in morin, becomes *olive;* when in red morin, deep brown; and when in white morin, a clear marron colour.

Fustic is employed to dye woollen cloth not merely yellow, but also green, bronze, and various compound colours. According to Bancroft, 4 pounds of this wood chipped, yield about as much colouring matter as 1 pound of quercitron bark. It gives a durable colour, which is not thrown down or made latent by acids so much as quercitrin yellow. On that account it is commonly employed with the solution of indigo in sulphuric acid in dyeing what are called Saxon greens.

SECTION III.—OF WELD.

Weld, in French *gaude* or *vaude,* is the dried leaves and stem of the *reseda luteola,* a plant which grows wild in Britain and in other European countries. Its leaves are long, narrow, and of a bright yellowish-green; but the whole plant is employed as a yellow dyestuff; though in this country its use has been very nearly superseded by other substances which yield a yellow colouring matter in greater abundance. There are two kinds of *weld,* the *cultivated* and the *wild,* the former of which is deemed more valuable than the latter, because it is much richer in colouring matter. When this plant is fully ripe, it is pulled, dried, and bound up in bundles for the use of the dyer. The wild species grows taller, and has a stronger stalk than that which is cultivated; so that the one may be readily distinguished from the other.

A decoction of this plant, if strong, has a brownish-yellow colour, and when diluted with water it acquires a shade of green. The acids render this colour more pale, while alkalies, common salt, and sal ammoniac render it deeper. Nitric acid, however, deepens the colour, and sulphuric acid makes it incline to brown. A solution of alum, or of protochloride of tin throws down a fine yellow lake. Sulphate of iron occasions a black precipitate, and sulphate of copper a brownish-green precipitate.

Chevreul discovered in *weld* a yellow colouring matter, which he

has distinguished by the name of *luteolin*. He obtained it by sublimation.*

It is crystallized in needles, some of which are long, transparent, and of a pale-yellow colour, others short, of a deeper yellow, and having a velvety aspect. It is very little soluble in water; yet though it gives very little colour to that liquid, it communicates to it the property of dyeing silk and wool, impregnated with the alum mordant, of a fine greenish-yellow colour. It is soluble in alcohol and ether. Solution of potash gives it a beautiful golden-yellow colour, which gradually passes into greenish-yellow, and at last reddish-brown, owing probably to the absorption of oxygen. Barytes water, strontian and lime water, and ammonia, produce similar effects.

Acetate of lead, alum, and acetate of copper precipitate the aqueous solution of luteolin yellow. Sulphated peroxide of iron throws it down olive-brown. Concentrated sulphuric acid produces a yellow colour with a tint of red, and reddish-brown flocks gradually precipitate. Concentrated sulphuric acid dissolves the crystals of luteolin; the solution is orange-yellow, with a shade of green, and when water is added to the solution a precipitate falls.

The yellow colour communicated by weld is more permanent than that communicated by quercitron bark, or by old fustic. In calico-printing Bancroft assures us that a heat nearly as high as that of boiling water is necessary to fix the colouring matter of weld, and the parts wanted to be kept white are then so much stained by it that the stain is very difficult to remove.† This is doubtless one of the reasons why weld is so little used in this country in calico-printing. Indeed the chrome-yellow has in a great measure superseded vegetable colouring matters in the operations of the calico-printers.

SECTION IV.—OF PERSIAN BERRIES.

The dye-stuff known among calico-printers by the name of Persian berries is the fruit of a variety of the *rhamnus infectorius*, which comes to this country from the Levant. These berries are larger than what are called Avignon berries, which are cultivated in the south of France; though it is believed that both are varieties of the same species of plant.

These berries are rich in a very beautiful yellow colouring matter; but unfortunately it is not fast. Hence the use of it of late years, since the discovery of chrome-yellow, is much less frequent than formerly. According to Chevreul, they yield to water among other bodies:—

1. A yellow colouring matter which is united to a substance insoluble in ether, and very little soluble in strong alcohol; but very soluble in water. Chevreul considers it as volatile.

2. A matter remarkable for the intensity of its bitterness, and which is soluble in water and alcohol.

* Leçons de Chimie appliquée à la Teincture, ii. 30 Leçon, p. 144.

† Bancroft on Permanent Colours, i. 409.

3. A red colouring matter, which exists in only a very small proportion in the berries, and which has a tendency to undergo decomposition, being changed into a brown substance on exposure to the air. It is found principally in the aqueous extract of the berries, insoluble in ether and alcohol.

When Persian berries are boiled for a quarter of an hour, in 10 times their weight of water, a brownish-yellow decoction is obtained, having a shade of green. It remains transparent when cold, has a peculiar smell, and a very bitter taste. Gelatin causes a slight precipitate in it, which does not fall down immediately.

Chloride of barium occasions no precipitate.

Nitrate of silver, a reddish-brown precipitate, soluble in nitric acid.

Oxalate of ammonia throws down lime.

Solutions of potash or ammonia change the colour to greenish-orange, without occasioning any precipitate.

Water of barytes, strontian, and lime, change it to greenish-orange, and throw down some flocks.

Protochloride of tin changes it to greenish-yellow, without occasioning a precipitate.

Alum diminishes the colour, and precipitates nothing.

Acetate of lead. 0.

Acetate of copper. A slight yellowish-red precipitate.

Sulphated peroxide of iron changes the colour to olive-green, without occasioning a precipitate.

Concentrated sulphuric acid weakens the colour, but precipitates nothing.

Nitric acid of 1·300 weakens the colour without producing a precipitate. An excess of acid develops a *beautiful brownish-red colour.*

Oxalic acid weakens the colour, and throws down oxalate of lime.

Acetic acid weakens the colour, and causes a very slight precipitate.

Iodine water produces no effect.

Chlorine deepens the colour to red: a greater quantity makes it pass into yellow.*

SECTION V.—OF ANOTTA.

Anotta, in French *rocou* or *roucou*, is a name given to the pulp of the seeds of the *bixa orellena*,† a shrub originally a native of South America, and now cultivated in Guiana, St Domingo, and the East Indies. It was used by the natives as a dye-stuff at the time of the discovery of America, and was made known in Europe soon after the conquest of Mexico by the Spaniards. The fruit of this plant is a coccus, containing from 30 to 40 seeds, smaller

* Chevreul, l. c. p. 174.

† Boussingault informs us that the word *bixa* is drawn from the ancient language of Hayti. *Rocou*, according to Humboldt, is derived from the Brazilian word *uruca*. See Ann. de Chim. et de Phys. xxviii. 441.

than a pea, and covered with a glutinous matter, having a vermillion-red colour. To extract this colouring matter, the grains are rasped down, water is added, and the whole is allowed to remain for some days. A sort of putrid fermentation takes place. The whole is then thrown on a drain, and the water which holds the colouring matter in suspension is collected. The colouring matter gradually subsides. It is taken out and dried in the shade. It is made up into small cakes, which come to Europe under the names of anotta and rocou.*

This process yields a very impure matter; on this account the process followed at Santa-Fé de Bogota is preferable. It consists in rubbing the grains of the bixa orellana against each other under water. As the colouring matter is merely superficial, it is easily rubbed off without loading the water with the mucilaginous matter contained in the interior of the seeds. The colouring matter being allowed to settle, the water is drawn off, and the anotta left to dry. When prepared in this way it is called *achiote*, in the country where it is produced.

Anotta thus prepared has a fine red colour. It is a homogeneous paste of the consistence of butter, has a fatty feel, and is not the least earthy in its aspect. When dried, the colour becomes deeper, and not so beautiful. It has no taste; but a disagreeable smell, resembling that of putrid urine.† When heated it softens, takes fire, and burns with much flame and smoke, leaving a bulky and very brilliant charcoal.

Water dissolves it in small quantity, and acquires a pale yellow colour. Alcohol is a much better solvent. The solution, when made at the ordinary temperature of the atmosphere, has a beautiful orange colour. When subjected to spontaneous evaporation, we obtain the colouring matter of anotta in the state of a powder. Ether dissolves it in still greater quantity than alcohol. The solution has a reddish-orange colour.

Caustic potash, and the alkaline carbonates, dissolve anotta abundantly. The solutions have a deep-red colour. The acids precipitate it from these solutions in a very fine powder.

Chlorine speedily discolours the alcoholic solution of anotta. The liquid becomes white and milky.

Muriatic acid has no action on anotta. The same remark applies to acetic acid. But when concentrated sulphuric acid is poured on it in powder, it assumes almost immediately a fine indigo blue colour. By degrees the colour loses its beauty, passes into green, and in 24 hours assumes a violet hue. According to Vogel and Bouillon Lagrange, sulphuric acid produces the same effect on the colouring matter of saffron.

The action of nitric acid, at the usual temperature of the air, on

* Boussingault, Ann. de Chim. et de Phys. xxviii. 441.

† This smell is not natural, but is communicated to it in the magazines by adding to it urine from time to time, in order to keep it moist and improve its colour. French anotta, not adulterated, smells of carrots.

anotta, is weak. It communicates a green colour, which soon passes into yellow. When a gentle heat is applied, nitrous vapours are given off, the anotta assumes the consistence of a syrup, and some minutes after the whole takes fire, and burns rapidly, leaving a charcoal in the state of minute division.

It dissolves readily in oil of turpentine. The fixed oils dissolve it also. The aborigines of America employ a solution of it in a fixed oil as a paint, under the name of *onoto*.*

According to Chevreul, anotta contains two colouring matters, the one *yellow*, and the other *red*. The yellow colouring matter is soluble in water and alcohol, and slightly so in ether. It gives a yellow colour to silk and wool, impregnated with the alum mordant. The red colouring matter is very little soluble in water. But it dissolves in alcohol and ether, to which it communicates an orange-red colour. It dissolves also in potash ley, and the solution has a deep orange-red colour. It is this colouring matter which has the property of being changed into blue by sulphuric acid, as Boussingault first observed.†

The price of anotta in France is usually about sixpence a pound. But sometimes it rises as high as half a crown. When this happens it is very common to adulterate it with powder of bricks, colcothar, &c. This adulteration is easily detected by exposing anotta (previously dried at 212°) to a red heat till it is quite burnt. If the anotta be pure, the residual matter will not exceed 13 per cent. Whatever is beyond that quantity is adulteration.‡

SECTION VI.—OF TURMERIC.

Turmeric is the root of the *curcuma longa*, a plant, which is a native of the East Indies, and which grows abundantly in Malacca, Java, and Balega. It has been repeatedly cultivated in England. The root, in its dried state, has been long known, and passed under various names, as *crocus sativus*, *terra merita*. Externally it is of a pale-yellow colour, wrinkled, solid, ponderous, and internally of a deep-saffron or gold colour. Its odour is somewhat fragrant, and to the taste it is bitterish, slightly acrid, exciting a moderate degree of warmth in the mouth, and on being chewed it tinges the saliva yellow. It has been much employed in dyeing; but unfortunately the colour which it imparts, though very beautiful, is not fixed. In India it is much used for colouring and seasoning of food; indeed, it is an essential ingredient in the curry powder, now so much used in this country.

The root of the *curcuma longa* was examined by MM. Vogel and Pelletier,§ and found composed of

1 Lignin.
2 Starch.

* Boussingault, Ann. de Chim. et de Phys. xxviii. 441.

† Chevreul. Leçons de Chimie appliquée à la Teincture, vol. ii. 30 Leçon, p. 186.

‡ See M. Girardin, Jour. de Pharm. xxii. 101.

§ Chevreul, l. c. Leçon 30, p. 178.

3 A yellow colouring matter, *curcumin*.
4 A brown colouring matter.
5 A little gum.
6 A very acrid volatile oil.
7 A little chloride of calcium.

The yellow colouring matter of turmeric, called *curcumin* by Chevreul, may be obtained by digesting turmeric in boiling alcohol, filtering the solution, and evaporating it to dryness. The residue being digested in ether, the *curcumin* is dissolved, and the brown-coloured matter left untouched. The ether being evaporated the curcumin is obtained, mixed with some volatile oil, and some chloride of calcium.

Curcumin is solid, heavier than water, of a reddish-brown colour when in lumps, but yellow when in powder. When heated to 104° it melts, and then swims on water. When kept in fusion and exposed to the air it loses its volatile oil.

It deliquesces slightly in a moist atmosphere, because it always contains some chloride of calcium.

It is very little soluble in water, even at a boiling temperature. The solution is yellow. Alcohol and ether dissolve it readily. The concentrated solutions have a reddish-orange colour with a tint of brown. The dilute solutions are yellow.

It is soluble in volatile and fixed oils, and in melted tallow.

Its alcoholic solution, when poured into a solution of gelatin, occasions a precipitate, composed of gelatin and curcumin in combination, insoluble in alcohol.

Potash, soda, barytes, and strontian, change the colour of curcumin into reddish-brown. Hence the employment of turmeric as a reagent to determine the presence of an alkali. Potash and soda dissolve a considerable quantity of it.

Many metallic oxides make with it compounds, whose colours vary from reddish-yellow to reddish-brown. Thus the alcoholic solution of curcumin precipitates the chloride of tin reddish; the acetate of lead, red marone; the nitrates of silver and mercury, reddish-yellow. Neither chloride nor sulphate of iron occasion a precipitate, but they change the colour to a deep brown.

Carbonate of potash does not change the colour of curcumin.

Concentrated sulphuric acid dissolve it. The solution has a carmine-red colour. When water is added the colouring matter precipitates in yellow flocks. Sulphuric acid diluted with four times its weight of water has no action on it. Muriatic acid and phosphoric acid, whether concentrated or dilute, act as sulphuric acid. The same remark applies to nitric acid, unless it be employed in excess.

Boracic acid does not alter the colour of a solution of curcumin in alcohol. But if the mixture be evaporated, a carmine-red matter is deposited, which has been described by Trommsdorf.

Acetic acid dissolves curcumin without altering its colour—phosphoric, sulphurous, and carbonic acids, and almost all the vegetable acids, have no sensible action on this colouring matter.

When curcumin is distilled it gives out a brown oil, water, acetic acid, carburetted hydrogen, and carbonic acid, and leaves a charry matter in the retort. Nitric acid, when concentrated and assisted by heat, decomposes it.*

SECTION VII.—OF SAFFRON.

What is called *saffron*, consists of the dried stigmas of the flower of the *crocus sativus*, a plant, which is a native of the western parts of Europe. Indeed, it is a native of England, and is abundantly cultivated in Great Britain, and English saffron is preferred to what is imported from abroad, and may be distinguished by its parts being larger and broader.

In Cambridgeshire, where the plant is chiefly cultivated, the saffron is prepared in the following manner:—In autumn when the flowers appear they are gathered every morning, and are spread upon a table; the stigmata, along with a portion of the style, are then picked from the other parts of the flowers, which are thrown away as useless. The stigmata being thus collected in sufficient quantity, are then dried, which is effected by means of portable kilns of a peculiar construction, over which a hair-cloth is stretched, on which are placed a few sheets of white paper, and on them the stigmata are strewed about 2 or 3 inches thick. They are then covered with sheets of paper, over which is laid a coarse blanket, five or six times folded, or a canvas bag filled with straw. And when the fire has heated the kiln, a board, on which a weight is put, is placed upon the blanket, in order to press the saffron into a cake. For the first hour a pretty strong fire is employed. The saffron is then found to be pressed into a cake, which, after being turned, is subjected for another hour to the same degree of heat. It is then turned a a second time, and a more gentle heat is applied for about 24 hours, or till the cake becomes dry, during which time it is turned every half hour.†

The colouring matter of saffron was first examined by Bouillon Lagrange and Vogel in 1811.‡ They distinguished it by the name of *polychroite*, on account of the numerous colours which it is capable of assuming.

To obtain polychroite, from an infusion of saffron in water, evaporate it to the consistence of honey; digest this residue in alcohol of 0·800, and evaporate the alcoholic solution to dryness. What remains is *polychroite*.

Its colour is intensely yellow. When exposed to the air it absorbs moisture, and becomes a viscid liquid. It is very soluble in water and alcohol; but insoluble, or nearly so, in ether. When the aqueous solution of polychroite is exposed to the rays of the sun it becomes colourless, and the yellow colour cannot be again restored. When sulphuric acid is dropped into the aqueous solution of this colouring

* Chevreul, l. c. Leçon 30, p. 178.
† Douglas, Phil. Trans. for 1728, Vol. xxxv. p. 566.
‡ Ann. de Chim. lxxxi. 188.

matter, the liquid assumes a deep indigo-blue colour, which gradually becomes lilac. The same change is produced by sulphuric acid on the alcoholic solution.

Nitric acid causes these liquids to assume a green colour. The addition of a little water causes this colour to disappear; and when the proportion of acid is increased, other shades make their appearance. Chlorine destroys the colour of these liquids altogether.

Sulphate of iron throws down a dark-brown precipitate, lime-water a yellow precipitate, and barytes water a red precipitate. Diacetate of lead throws down a saffron-coloured precipitate; acetate of lead produces no effect, but nitrate of mercury throws down a red powder.

Polychroite is insoluble in oils. When it is distilled there comes over an acid water, and an oil of a lemon-yellow colour, which is succeeded by an oil of a darker colour, and almost brown. At the same time carbonic acid and carburetted hydrogen gases are disengaged. When the charcoal that remains behind is calcined with potash, hydrocyanic acid is formed.

Saffron is employed in medicine chiefly as a colouring matter. It was used by the ancients, and is mentioned by Dioscorides under the name κροκος, and by Pliny under that of *crocus*. He mentions the medicinal uses to which it was applied in his time.* The Arabians seem to have distinguished it by the name of *zaffaran*: hence our term saffron. It is used occasionally as a paint. As a dye-stuff it communicates a very beautiful colour; but as it is fugitive, it is hardly, if at all, employed in dyeing in this country.

SECTION VIII.—OF SUMAC.

Sumac, called also *young fustic* by the British dyers, is the dried and powdered branches of the *rhus coriaria*, a shrub which grows spontaneously in Italy and the south of France, where it is cultivated for the use of the dyers, and for tanning leather. For this last purpose, as we learn from Dioscorides, it was employed by the ancients.

Sumac has not been subjected to any chemical analysis. But it is obvious, from the uses to which it is put, that it contains two substances of considerable importance; namely, tannin, and a yellow colouring matter. Hence when cloth impregnated with the alum mordant is passed through a decoction of sumac, it is dyed yellow, and when impregnated with acetate of iron it is dyed grey or black by sumac, according to the strength of the acetate of iron employed.

To dye with sumac, the water ought to be raised to the temperature of 122°. The sumac is put into it at that temperature, then the cloth is added and kept in it about 15 minutes, while, at the same time, the heat of the liquid is increased. If the heat be raised too high, or if the cloth be left too long in the liquor the colour becomes paler, and, indeed, that given by means of acetate of iron disappears almost entirely.

* Hist. Nat. lib. xxi. c. 20.

We obtain a very pretty grey upon cotton by plunging it alternately into dilute solutions of sumac and sulphate of iron. The colour is the more uniform the weaker the solutions are, and the more frequently the alternate dips of the cloth are repeated. We must finish by dipping the cloth into sulphate of iron, because if we terminated by dipping it into solution of sumac the colour would be yellowish-brown. When stronger solutions are employed we obtain a *black*, which becomes beautiful and pretty fixed, when we pass the cloth through a decoction of logwood in which some acetate of copper has been dissolved.

The colour given by sumac when used as a dye-stuff is an orange-yellow; but as it is by no means a fixed colour, it is seldom used in this country as a dye-stuff, though it is in common use as a substitute for nutgalls in the Turkey-red dye.

During the continuance of the Continental system adopted by Bonaparte, after the battle of Jena, great quantities of sumac were raised in Hungary, which were sent into Germany, where it was used as a dye-stuff, under the name of *yellow wood*, or *fustic*. Vienna alone consumed 100,000 lbs. of it. Before the introduction of the morus tinctoria, and the quercitron bark, sumac was much employed as a dye-stuff; but these substances have, in a great measure, superseded its use.

SECTION IX.—OF RHEIN, OR RHAPONTICIN.

This substance, which possesses acid properties, has been already described, while treating of vegetable acids.

SECTION X.—OF CHAYA-VER.

This is the root of the *oldenlandia umbellata*, a plant which grows in India, on the sandy coasts of Coromandel and Java, and which has long been employed in that country in dying nankin and various shades of yellow. It is described by Roxburgh, and a good account of it will be found in the *Edinburgh Transactions* for 1794, p. 16. A good deal of it was brought to England in 1774, but the English dyers at that time had not skill enough to make use of it. It has however been long known, that in order to make it fit for dyeing, nothing more is necessary than to dissolve in the water in which it is to be lixivated a little carbonate of soda. The colouring matter then dissolves in the water, and it possesses this remarkable property that it becomes fixed on the cloth without its being necessary to employ any mordant.*

SECTION XI.—OF YELLOW FLOWERS.

The colour of yellow flowers, whether pale or deep, is much more durable than that of blue or red flowers. They in general dry well, and give out their colouring matter both to water and alcohol. Neither acids nor alkalies alter the yellow colour of flowers, though

* See Jour. de Pharmacie, Gaultier de Claubry, xviii. 461, and Virey, ibid. 517.

both alter its shade, the acids rendering it paler, and the alkalies deeper. Alum likewise heightens the colour, though not so much as alkalies.

John informs us that the flowers of the *tropæolum majus*, which have a beautiful yellow colour, contain a colouring matter, which dissolves readily in water and in potash, communicating a brownish-yellow colour, which is altered to a *cherry-red* by the acids, to greenish-blue by carbonate of soda, and which is precipitated yellow and red by several metallic salts.*

According to Caventou, the flowers of the *narcissus pseudonarcissus*, contain two yellow colouring matters. If we digest the flowers in ether, we obtain, by evaporation, a yellow resin, which is at first semiliquid, but hardens on drying, and gives out a smell similar to that of the flower. It is insoluble in water and alcohol; but dissolves readily, and without undergoing decomposition in nitric and muriatic acids, and also in alkalies. These solutions have a yellow colour. If we boil the petals, previously digested in ether, in alcohol, of the specific gravity 0·820, another yellow colouring matter is dissolved, which remains after the evaporation of the alcohol. When in thin crusts it has a fine greenish-yellow colour; but when in thick masses a brown. It dissolves readily in water, and, when dry, absorbs humidity from the atmosphere. The acids render it paler; the alkalies change it to brown. Alum does not precipitate it unless we add to the alum a quantity of alkali; it then lets fall a fine yellow precipitate. A similar coloured powder falls when acetate of lead is poured into a solution of the colouring matter.†

The *parmelia parietina* (*Lichen parietinus* of Linnæus) so common upon walls and trees, has a fine yellow colour, and contains, according to Schrader, a colouring matter soluble in boiling alcohol. When the solution cools, this colouring matter crystallizes in long brilliant plates. When gently heated they melt, and, on cooling, concrete into a mass difficult to pulverize. This colouring matter is insoluble in water, though that liquid does not precipitate it from its alcoholic solution. It is soluble in ether, and in alkalies, which change its colour to a deep red.‡

Besides the colouring matters enumerated in this Division, many others have been occasionally employed as yellow dyes. The following among others may be mentioned:—

Serratula tinctoria, sawort.
Genista tinctoria, dyers' broom.
All the species of *heath* which are natives of Britain.
Salix pentandra, sweet willow.
Solidago canadensis, American golden rod.

* John's Chemische Untersuchungen, iii. 112.
† Ann. de Chim. et de Phys. iv. 321.
‡ Berlin Jahrbuch, 1819 p. 44.

Heleborus trifolius, three-leaved hellebore.
Anthemis tinctoria.
Fraxinus excelsis, ash.
Fumaria officinalis.

But of these no accurate chemical examination has been hitherto made.

DIVISION IV.—OF GREEN COLOURING MATTERS.

Though *green* be the paramount colour of the vegetable kingdom, we are not acquainted with any vegetable principle which can be used as a *green* dye. *Green* is in fact a compound colour, and is always induced upon cloth, by dyeing it first *yellow*, and then *blue*; it being well known that blue and yellow together constitute *green*. There are, however, a few green matters which may be extracted from vegetables, and which deserve to be noticed.

SECTION I.—OF CHLOROPHYLLITE, OR CHROMULITE.

The name chlorophyllite has been given by Pelletier and Caventou to the green colouring matter of the leaves of plants.* It was afterwards changed into *chromulite* by M. Decandolle.† It is obtained by bruising the green leaves into a pulp with water, pressing out all the liquid, and boiling the dry pulp in alcohol. When the alcohol is evaporated, the chlorophyllite remains in the state of a deep-green matter, which may be rendered pure by digesting it in water, that liquid dissolving and freeing it from a little brown colouring matter, with which it was mixed.

When this substance is exposed to the air it undergoes no sensible change. When heated it softens; but does not melt. When the temperature is farther raised, the chlorophyllite is decomposed, without giving out any trace of ammonia. It burns with flame, and leaves a bulky charcoal which is easily incinerated.

Hot water dissolves a small quantity of it, but as it cools the chlorophyllite separates. Acetic acid is the only one of the vegetable acids which acts as a good solvent of it.

Concentrated sulphuric acid, dissolves it cold without alteration. The addition of water causes a portion of it to precipitate, and the rest may be obtained by saturating the acid. The alcoholic solution of chlorophyllite is not altered when mixed with its own weight of sulphuric acid. When the solution of chlorophyllite in sulphuric acid is kept, the colouring matter is gradually destroyed.

Muriatic acid, and still better nitric acid, destroys chlorophyllite; but neither mucic nor oxalic acid is formed. Iodine and chlorine both destroy this substance; but the chlorine most rapidly.

If we mix an earthy or metallic salt with the alcoholic solution of chlorophyllite, and then add an alkali or carbonate, a copious precipitate falls, consisting commonly of chlorophyllite combined with

* Ann. de Chim. et de Phys. ix. 194. † Ibid. xxxviii. 422.

the base of the earthy or metalline salt. In this way various green coloured lakes may be obtained, which in general preserve their colour very well.

M. Macaire Princep ascertained that in order to obtain chlorophyllite pure, the leaves ought to be previously digested in ether.* When the leaves of the *populus fastigiata* were digested in boiling ether, the liquid assumed a light yellow colour, and deposited on cooling a quantity of wax. By evaporation a white solid fatty matter was obtained.

It is well known to every person that the green leaves of deciduous trees change in the autumn to yellow or red before they fall off the trees. From the observations of Macaire Princep it appears that these three colours are modifications of the same colouring matter. The autumnal tint of the leaves only takes place when they are exposed to the light of the sun. When exposed to light the leaves absorb oxygen gas during the autumn; though they gave out that principle before. The consequence of this absorption is the formation of an acid, which changes the chlorophyllite first to yellow and then to red. If we macerate a red leaf in potash it becomes green; but the acids give it a yellow colour. The same change of colour takes place when green leaves are treated with an acid. The yellow and red colours have more analogy with the resins than with wax. After having removed the wax from a leaf by ether, we may dissolve the yellow or red chlorophyllite in alcohol. The alkalies change this solution into green. M. Macaire Princep concludes from his experiments that the red and yellow colour of flowers is the same as that which exists in leaves which have assumed the yellow tint of autumn. In consequence of this view of the subject, M. Macaire Princep proposes, with Decandolle, to change the name chlorophyllite into *chromulite*, that the name may not indicate one determinate colour. But I rather think that his conclusions are drawn from too limited a number of experiments.

SECTION II.—OF SAP-GREEN.

What is called in this country *sap-green*, and in France *vert de vessie*, is the inspissated juice of the ripe or semi-ripe berries of the *rhamnus catharticus*, or common *buckthorn*, a plant which grows wild in Great Britain, and in most European countries. This species of green matter is entirely different from chlorophyllite.

It is soluble in water. Carbonate of soda and caustic potash change the solution of sap-green to yellow. Hence paper tinged with sap-green is a sensible test of alkalies.

Sulphuric, nitric, and muriatic acids make it red. Carbonate of lime, added to a reddened solution, restores the green colour, which therefore appears to be the proper colour of this substance.†

SECTION III.—OF COFFEE-GREEN.

Green coffee beans contain a matter partly volatile, to which

* Ann. de Chim. et de Phys. xxxviii. 419. † Smithson, Phil. Trans. 1818, p. 116.

alkalies impart a green colour. If we digest one part of green coffee in 2 parts of alcohol, containing in solution a fourth part of its weight of soda, for two hours, assisting the digestion by a moderate heat, we obtain a green-coloured liquid, which, when evaporated to dryness, leaves an exceedingly beautiful green matter.

Leuchs ascertained, that when alkaline leys are digested on green coffee, a yellow matter is dissolved, which becomes emerald-green by the action of the air, and at last passes into a deep bluish-green. The green colouring matter may be fixed upon cloth.*

The decoction of green coffee beans is brownish, and has but a weak colour. Alkalies change it to a fine yellow. Alum does not sensibly alter the colour. Sulphate of iron renders it blackish. Wool impregnated with the alum mordant is dyed yellow by it; but the colour does not resist the action of the sun. Cotton and linen impregnated with alum and verdigris do not imbibe a green colour from it, showing that the colouring matter as soon as it is oxidized has no affinity for cloth. In this respect it resembles indigo.

DIVISION V.—OF WHITE FLOWERS.

Even white flowers are by no means destitute of colouring matter. Many of them strike a green with alkalies, though acids do not render them red. Some of them seem to contain the same colouring matter as yellow flowers. Thus the petals of *convolvulus sepium*, though white, give a deep yellow or orange colour to water, which is rendered paler by acids, and heightened by alkalies and alum. The vapour of sulphurous acid does not alter white flowers, though it destroys the colour of all others.†

CHAPTER VII.

OF FIXED OILS.

There seems little reason to doubt that the fixed oils constitute, in reality, salts, or rather each oil is a mixture of two or more salts; if the term salt can be applied to the compounds of the oily acids with *glycerin*, which acts the part of a base. But not being in possession of an easy method of separating these oily acids from each other, this important point has been established only in a few cases. All that can be done, therefore, in the present imperfect state of our knowledge, is to describe each of the fixed oils separately, so far as they have been subjected to chemical examination. For

* Leuchs, Traité des Couleurs, i. 204. † Lewis, Neumann's Chemistry, p. 432.

it will be only from these minute details that general facts can be deduced, in order to form an accurate theory of oily bodies.

In the *Chemistry of Inorganic Bodies* (vol. ii. p. 346), the general characters of the fixed oils have been given, and their constitution stated, as far as known. Their division into *drying* oils, *fat* oils, and *solid* oils, has been stated, and a list of the most important oils belonging to each class has been given. It remains here to enter into some details respecting such of the oils belonging to each of these classes, as from their importance seem entitled to particular mention.

DIVISION I.—OF DRYING OILS.

These oils gradually dry when exposed to the air into a hard transparent varnish, which does not stain the fingers. The most important of them are the following :—

SECTION I.—OF LINSEED OIL.

This oil is obtained by expression from the ripe seeds of the *linum usitatissimum*, or common *flax*, which furnish about 22 per cent. of their weight of it. It has a light-yellow colour, and a peculiar smell and taste. It may be cooled down to 4° without undergoing any other change than becoming paler in the colour; but at —17° it congeals into a solid yellow mass. According to Gusserow it becomes solid at 3°, provided that temperature be continued for several days.

It dissolves in 5 times its weight of boiling alcohol, and in 40 times its weight of cold alcohol, and in 1·6 times its weight of ether. Unverdorben has particularly examined the changes which this oil undergoes when long kept, or when it dries.

When kept in a cellar and in a vessel imperfectly shut, it gradually deposits a white, fatty, soft sediment, and a brownish powder. The fat body is *stearin*, mixed with a substance insoluble in ether, and possessing the characters of vegetable albumen. The solution of the stearin in ether deposits crystals when left to spontaneous evaporation. This stearin is soluble in 100 times its weight of cold, and 40 times its weight of boiling alcohol. It dissolves in 50 times its weight of cold, and 20 of boiling ether. It is very difficult to convert this stearin into soap.

One-fourth part of the *brown powder* dissolves in water. The solution contains a substance analogous to gum, which is precipitated both by the dilute acids and the acetate of copper, and is neither soluble in alcohol nor ether. The remaining $\frac{3}{4}$ths of this brown powder are insoluble in most menstrua. The hydrate of potash extracts from it a little resin.

To study the substance formed during the drying of this oil, Unverdorben triturated the oil with a sufficient quantity of chalk to render the whole pulverulent, and left it for four weeks exposed in a warm place. At the end of this time the oil was completely dried. The chalk was dissolved by dilute muriatic acid. The residue

being treated with ether, an unctuous matter was dissolved, having the consistence of tar. This matter was altered *oleic acid*, and amounted to 0·15 of the oil.

The residue insoluble in ether, freed by a new quantity of muriatic acid from any remains of chalk which it still retained, was dry linseed oil. It constituted a yellowish mass, and was insoluble in water, alcohol, and ether. When put into ether it swelled; but when the ether evaporated it resumed its original appearance. It was insoluble in the fixed and volatile oils. When treated with a mixture of muriatic acid and alcohol, it was converted into a tarry-looking matter. It was dissolved and decomposed by a solution of 1 part of hydrate of potash in 6 parts of water. The solution contained oleate of potash, and a compound of potash with a tarry matter, insoluble in water.

When linseed oil is converted into the *varnish* for printers' ink, described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 350), it undergoes the same alteration as when thus dried. The oil is boiled gently for 5 or 6 hours; and it has been ascertained that the longer the boiling continues, and the gentler it is, the better does the varnish prove. It is usual to add from 2 to 4½ ounces of litharge for every imperial gallon of linseed-oil boiled, and about ½ ounce of sulphate of zinc. The litharge, during the boiling, is mostly reduced to the metallic state, and may be found at the bottom of the oil in the state of a grey powder. Linseed oil thus prepared, is fit for constituting the basis of oil paints and varnishes. When linseed oil is mixed up with white lead as a white paint, it is not boiled before being used; because the boiling deepens the colour, and, of course, would injure the beauty of the paint.

When linseed oil is long kept in a bottle only half filled with it, it becomes thick, and then does not dry well. In this state it is more soluble in alcohol than the fresh oil, and its solution is added with advantage to varnishes to diminish their brittleness.

SECTION II.—OF OIL OF WALNUTS.

This oil, expressed from the fruit of *Juglans regia*, when fresh has a greenish colour; but when long kept it becomes pale-yellow. It has no smell, and its taste is agreeable. It becomes thick at 5°, and at —17° freezes into a white mass. It is more dessicative than linseed oil, and is used in the finer kinds of painting. Walnuts are said to yield half their weight of oil.

Saussure found that this oil absorbed 15·5 times its bulk of oxygen gas, and gave out a quantity of carbonic acid gas, amounting to about $\frac{2}{13}$ths of the bulk of the oxygen absorbed.*

SECTION III.—OF OIL OF HEMPSEED.

This oil is obtained by expression from the seeds of *canabis sativa*, or *hemp*. When fresh drawn it is greenish-yellow, but

* Ann. de Chim. et de Phys. xlix. 230.

becomes yellow by keeping. Its smell is disagreeable; but it has little taste. It dissolves in all proportions in boiling alcohol; but cold alcohol dissolves only the 30th of its weight. At 5° it becomes thick, and at —17° it freezes like oil of walnuts. It is used for lamps in Russia and other countries; but it is apt to form a viscid varnish, difficult to remove from the lamp. It is also used for making soap, and in varnishes.

Saussure left hempseed oil for four years in contact with oxygen gas over mercury. The oxygen absorbed was 138·4 times the bulk of the oil. The bulk of the residual gas was 0·2234, or about $\frac{10}{44}$ths of the original gas. It was composed of

Carbonic acid	90·7
Azotic	17·8
Hydrogen	26·4
Oxygen	3·6
	138·5*

SECTION IV.—OF POPPY OIL.

This oil is obtained by expression from the seeds of the *papaver somniferum*. It resembles olive oil in its appearance and taste. Its specific gravity is 0·9249 at 59°. It congeals at zero, or about half a degree lower. It requires 25 times its weight of cold, and 6 of boiling alcohol to dissolve it. It unites in all proportions with ether. In France and Germany it is used as an article of food.

SECTION V.—OF CASTOR OIL.

This oil, the *oleum ricini* of the Pharmacopeia, is obtained by expression from the seeds of the *ricinus communis*, a biennial plant, cultivated in the West Indies. It seems to be the κικι or κροτων of Dioscorides,† who mentions that the seeds are powerfully cathartic. When expressed from the seeds cold it is quite transparent, and has only a slight tinge of yellow; but when obtained by boiling, it has most commonly a deeper shade of yellow. It possesses considerable viscidity. Its specific gravity at 77° is 0·9575, as determined by Saussure. It has no smell, and its taste is scarcely perceptible. It boils, according to Bussy and Lecanu, when heated to 509°, and may be partly distilled without the evolution of any gas, but emitting a very peculiar smell. When about a third of the oil has been distilled over, gas is disengaged in abundance; and this gas is inflammable. When cooled down to zero it congeals into a yellow transparent mass. When exposed to the air it thickens, and becomes rancid, its colour at the same time deepening.

It may be mixed in all proportions with alcohol and ether, and when so mixed it lets fall the foreign bodies with which it may have been mixed. This solubility in alcohol constitutes a remarkable difference between castor and other fixed oils.

* Ann. de Chim. et de Phys. xlix. 229. † Dioscorides lib. iv. c. 164.

According to Bussy and Lecanu* it gives, when distilled and converted into soap, products different from the other fixed oils. After a third part of the oil has been distilled over, there remains a peculiar substance, which is solid at the ordinary temperature of the atmosphere, and insoluble in oils, alcohol, and ether. Sulphuric, nitric, and muriatic acids scarcely act on it. But it is dissolved when boiled in a solution of caustic potash or soda. The oil distilled over is colourless, it crystallizes during the cooling, and has a strong smell. This oil is accompanied by two acids, distinguished by their acridity, and by forming with magnesia and oxide of lead salts, which are very soluble in alcohol.

When castor oil is mixed with $\frac{1}{20}$th of its weight of hyponitrous acid (diluted with thrice its weight of nitric acid) it becomes solid in about seven hours. It first assumes a golden-yellow colour, and at last changes into a translucent matter, having the consistence of wax. This change goes on about 8 times slower than with olive oil. The rapidity also is connected with the quantity of hyponitrous acid used. When it is only $\frac{1}{200}$th of that of the oil the solidification requires 60 hours. To the solid substance into which castor oil is thus converted, M. Boudet has given the name of *palmin*.†

Palmin has usually a yellow colour; but this colour is accidental, pure palmin being white. It is at first of the consistence of wax, but hardens by keeping, and assumes a resinous appearance. It melts at 151°, though when quite new the melting point is as low as 144°. It has a smell similar to that of the volatile oil obtained by Bussy and Lecanu when castor oil was distilled. But M. Boudet could extract no sensible quantity of oil from it by distillation.

Palmin is very soluble in alcohol and in ether. At the temperature of 86°, 100 parts of alcohol of 0·837 dissolve 50 parts of palmin. It is much more soluble in boiling alcohol; and when the liquid cools it is deposited in small opaline grains. When palmin is melted, ether dissolves it in all proportions. When treated with potash ley it is easily saponified, glycerin being separated at the same time. The soap is soluble in water, but is separated by the addition of chloride of sodium, undergoing at the same time decomposition. When this soap is dissolved in water, and the solution mixed with muriatic acid, an acid is separated, which, on cooling, concretes into a crystalline mass. This is the *palmic acid* of M. Boudet.

Palmic acid when pure, fuses at 122°. It is purified by pressure between folds of paper, and by solution in alcohol and crystallization. The crystals are white silky needles. Palmic acid is soluble in all proportions in alcohol and ether. But its solubility in alcohol diminishes as that liquid contains more water. It requires 5 times its weight of alcohol of 0·915 to dissolve it at the temperature of

* Jour. de Pharmacie, xiii. 57. † Ann. de Chim. et de Phys. l. 413.

122°. It reddens litmus paper strongly, combines with bases, and decomposes the carbonates.

Palmate of soda is obtained by mixing palmic acid with a solution of carbonate of soda, evaporating to dryness, and digesting the residue in alcohol, which dissolves the palmate of soda alone. The alcoholic solution of palmate of soda, when cooled, assumes the form of a jelly. This salt does not crystallize. When treated with a great deal of water, one-half of the base is removed, and a bipalmate of soda formed.

Palmate of ammonia may be obtained in the same way. It does not crystallize.

Palmate of magnesia is soluble in hot alcohol, and is deposited in scales as the solution cools.

Palmate of lead is soluble in hot alcohol, and assumes the form of a jelly when the solution cools. But if the solution be dilute it deposits silky needles.

Palmate of lime is soluble in boiling alcohol.

Palmate of copper, obtained by double decomposition, has a fine green colour. It is sensibly soluble in alcohol of 0·817.

Palmate of silver is insoluble in alcohol and water, but soluble in ammonia. It was analyzed by M. Boudet, who found it composed of

Palmic acid . .	66·75 or 29·10
Oxide of silver . .	32·25 or 14·5
	100

According to this analysis the atomic weight of palmic acid is 29·10.

When palmic acid is distilled, about $\frac{9}{10}$ths of it passes over in a butyraceous state. It contains a quantity of the volatile acid from castor oil obtained by Bussy and Lecanu. Most of the rest is palmic acid unaltered.

When palmin is distilled it gives the same products as castor oil. No palmic acid seems to be formed.

Nitric acid and sulphurous acid are capable of solidifying castor oil as well as hyponitrous acid. The theory of this curious change produced in the oil is still obscure.*

Castor oil is well known, and in constant use as an excellent purgative. Its purgative qualities were ascribed to an acrid substance contained in the seeds; but Guibourt has shown that this acrid substance is so volatile, that it is driven off by the temperature necessary to extract the oil from the seeds.

M. Subeixran extracted an acrid resin from castor oil, by the following process:—The oil was saponified, taking care not to add an excess of alkali. The soap was dissolved in water, and precipitated by chloride of calcium. The precipitate was washed and boiled in strong alcohol. Most of the soap is deposited as the

* Boudet, Ann. de Chim. et de Phys. l. 411.

solution cools. The alcoholic solution is evaporated to dryness, and digested in ether. The portion of soap present is dissolved, and the acrid resin, in very small quantity, remains.* It is not unlikely that the minute quantity of resin thus obtained is formed during the process. It cannot account for the cathartic qualities of castor oil.

The oil is quite destitute of all acridity. In this country, we prefer cold drawn castor oil as a purgative: in France, they consider the oil obtained by cochen as the best. In all likelihood there is very little difference in their medical qualities, but the cold drawn oil is most agreeable to the eye.

SECTION VI.—OF CROTON OIL.

This oil is obtained by expression from the seeds of the *croton tiglium*, a tree which grows in the East Indies. It had been employed in medicine above a century ago; but its action was so uncertain, being sometimes very violent, and sometimes nearly inert, that it was laid aside, but its use has been again revived in our own days. A single drop of the oil constitutes a dose, and generally acts as a sufficient purgative.

Croton oil is yellow like honey, and about the consistence of oil of walnuts. Its smell resembles jalap, its taste is acrid, and irritates the throat. Alcohol and ether dissolve it. It owes its purgative qualities to a portion of *crotonic acid* dissolved in the oil.

Dr Nimmo found that when the seeds were digested in ether, about 60 per cent. of their weight of oil might be extracted from them. Alcohol dissolved $\frac{2}{3}$ds of them, which possessed purgative properties; what remained had little taste, and no medicinal qualities. The crotonic acid may be isolated by saponification. The oil is mixed with magnesia and water, and the mixture evaporated to dryness. The oil is then separated, by digesting the whole in ether; and the magnesia residue is mixed with phosphoric acid and distilled. But by this process very little acid is obtained.

The best method of proceeding is to convert the oil into soap, by combining it with the requisite portion of potash. The soap is decomposed by tartaric acid, the whole filtered, and the liquid remaining is distilled in a well luted apparatus. An acid liquid comes over, having an acrid and disagreeable odour. Saturate with barytes water, evaporate to dryness, and decompose the barytes salt by phosphoric acid in a very concentrated state. The acid is distilled off, taking care to keep the receiver cool, and to have the joints of the apparatus well luted.

DIVISION II.—OF FAT OILS.

These oils, like the preceding, become solid by long exposure; but the solid formed has the appearance and properties of tallow.

* Jour. de Pharmacie, xv. 509.

SECTION I.—OF OLIVE OIL.

This oil is expressed from the pericarpium of the fruit of the *olea europea*, or common olive. Its usual colour is a pale yellow. Its specific gravity at 77° is 0·9109, as determined by Saussure. It congeals at the temperature of 36°, depositing little spheres of stearin, which sink to the bottom of the liquid portion of the oil. At 21° it deposits 28 per cent. of stearin, and leaves 72 per cent. of elain. The stearin, according to Gasserow, melts when kept a long time in the temperature of 50°. This, however, does not happen if the stearin be well freed from elain, by subjecting it to pressure between folds of blotting paper. Olive oil, at the temperature of 59°, dissolves in 1½ times its weight of ether, as determined by M. Lecanu.*

Three varieties of olive oil are met with in commerce. The best, called *virgin* oil, is obtained by gentle expression, cold. By a stronger pressure, and by the aid of boiling water, common oil of olives is obtained. And a still inferior oil is obtained, when the husk of the olive, after the former treatment, is boiled in water. This last oil is employed entirely in the manufacture of soap.

Saussure left olive oil for four years in contact with oxygen gas, standing over mercury. The oil absorbed 102 times its bulk of oxygen gas, and gave out at the same time carbonic acid and hydrogen gas. The residual gas amounted to 0·326, or nearly $\frac{1}{5}$d of the whole oxygen gas employed, and was composed of

Carbonic acid	81·7
Azotic	14·9
Hydrogen	23·2
Oxygen	4·2
	124·0†

M. Pomier has discovered that olive oil is capable of depriving wine of the musty taste which it acquires when it comes in contact with mouldy matter attached to the cask which contains it. All that is necessary is to agitate the wine with a quantity of olive oil, and then to allow the two liquids to separate by rest. The wine, when drawn off, will be found quite free from its musty taste. The efficacy of this process was verified by MM. Boullay and Chevallier, and the thanks of the Royal Academy of Medicine of Paris were given to the discoverer.‡

Olive oil is more employed than any other of the fixed oils. In the south of Europe, where the olive grows, the oil constitutes a common article of food, as butter is with us. In northern climates, on account of its high price, its use is restricted in a great measure to the making of salads, and dressing certain articles of food. What is used in this way, is often falsified with poppy oil or rapeseed oil. It is very important to be able to discover these sophistications.

* Jour. de Pharmacie, xx. 326. † Ann. de Chim. et de Phys. xlix. 226.
‡ Jour. de Pharmacie, xv. 17.

Poutet recommends* the following method for discovering the presence of poppy oil:—

Dissolve 6 parts of mercury in 7½ parts of nitric acid, of the specific gravity, 1·35. Mix 2 parts of this solution with 96 parts of the oil to be tested, and agitate the mixture well every half hour, or oftener. If the oil was pure, the mixture in 7 hours will assume the form of a thick magma, and in 24 hours it will become so hard as to oppose resistance to a glass rod pushed into it. Other fixed oils do not possess this property of combining with nitrate of mercury; and if the olive oil contains any other oil, the whole may become thick, but it will never become solid. If the quantity of foreign oil amount to $\frac{1}{8}$th, it will separate from the thick mass, and form a distinct layer, the thickness of which will depend upon the quantity of foreign oil present. Should the two oils have been mixed in equal quantities, the bulk of the fluid portion will be equal to that of the solid. The trial should be made at the temperature of 68°, at which the oil and the coagulum separate best from each other. If the olive oil has been adulterated with animal fat, the mixture coagulates in five hours. The coagulum in that case consists of the animal fat, and the greater part of the olive oil swims on the surface, and may be decanted off. The fat thus coagulated gives out, when heated, the smell of melted tallow.

M. Felix Boudet has shown that it is not the oxide of mercury, nor the nitrate of mercury, contained in Poutet's test liquor, that solidifies the olive oil; but the hyponitrous acid which it contains.† He found that half a grain of hyponitrous acid, mixed with thrice its weight of nitric acid, solidifies 100 grains of olive oil in about 78 minutes. All the fat oils tried by him, namely, oils of almonds, filberts, acajou, and colza, were solidified also; but none of the drying oils, except castor oil. But the time necessary for the solidification of each is very different. The following table shows the number of minutes that these oils take to solidify, when 100 parts of each are mixed with 12 parts of a mixture of nitric and hyponitrous acid, containing 3 parts of hyponitrous acid:—

Oils.	Colours which they take on adding the reagent.	Number of minutes before solidifying.	Ratios.
Olive Oil	Bluish-green	73′	10
Almond Oil	Dirty-white	160	22·2
Oil of Filberts	Bluish-green	103	14
Oil of Acajou	Sulphur-yellow	43	6
Castor Oil	Golden-yellow	603	82·6
Oil of Colza	Brownish-yellow	2400	328

M. Boudet has found that the presence of poppy oil in olive oil may easily be detected by the increased length of time that it takes to solidify with hyponitrous acid; 1 per cent. of popy oil retarding the solidification no less than 40 minutes.

* Ann. de Chim. et de Phys. l. 392. † Ibid.

To the solid matter into which olive oil is changed by means of hyponitrous acid, Boudet has given the name *elaidin*. It possesses the following characters:—

Its colour is white, or, if yellow, becomes white when digested in alcohol, which dissolves the colouring matter. Alcohol of 0·837 dissolves a very small quantity of it. It has no effect upon vegetable blues. If, after being digested in hot alcohol, it be exposed to pressure between the folds of blotting paper, it gives out a small quantity of oil, and may then be considered as pure elaidin. Its colour is not altered by potash, ammonia, or sulphohydrate of ammonia. It melts at 97°. Ether dissolves it in every proportion; but it requires 200 times its weight of boiling alcohol, of the specific gravity 0·8975, to dissolve it. The solution, on cooling, becomes muddy, but no crystals are formed.

It is easily saponified when mixed with potash or soda ley. Glycerin is evolved, and a fatty acid, which combines with the alkali, and forms the soap. The soap thus obtained is soluble in water, especially when hot; but assumes the form of a transparent magma on cooling. Muriatic acid decomposes this soap, when assisted by heat, and disengages the fatty acid, which appears first as a fluid oil, but on cooling concretes into a solid crystalline mass.

The acid thus formed has peculiar properties, and has been called by M. Boudet *elaidic acid*. It melts when heated to 111°, and strongly reddens litmus paper. When dissolved in hot alcohol, it is deposited, on cooling, in small pearly very brilliant scales, resembling boracic acid in appearance. Ether dissolves it in all proportions when it is melted. It is also soluble in all proportions in boiling alcohol. At the temperature of 97°, 1 part of alcohol, of specific gravity 0·915, is capable of holding in solution 5 parts of elaidic acid; while 60 parts of the same alcohol boiling, is scarcely capable of dissolving 1 part of margaric acid.

Elaidic acid may be distilled over almost completely without alteration. When heated with oxide of copper, it is converted into water and carbonic acid. It saturates bases, and separates the carbonic acid from the carbonates.

If we wish to form neutral elaidate of soda, we have only to heat elaidic acid with a solution of carbonate of soda. Evaporate the solution to dryness, and digest the residue in alcohol of 0·817. The elaidate alone is dissolved, and when the solution cools, it crystallizes in silvery scales, lighter and more brilliant than the elaidic acid itself. This salt dissolves readily in hot water, and when cautiously cooled, crystallizes in needles.

Elaidates of potash and *ammonia* may be obtained in the same way. The former of these crystallizes in light brilliant needles. They are both soluble in alcohol and in water, especially when hot.

The insoluble elaidates are easily formed by double decomposition.

Elaidate of magnesia is not sensibly soluble in water. It is very soluble in alcohol of 0·817.

Elaidate of lead is insoluble in water; but rather more soluble in alcohol than elaidate of magnesia.

Elaidate of mercury is slightly soluble in ether.

M. Boudet analyzed elaidate of silver, and found it composed of

Elaidic acid . .	70·125 or 34·06
Oxide of silver .	29·875 or 14·5
	100

According to this determination, the atomic weight is 34·06.

When elaidin is distilled it yields abundance of gas, and a liquid passes over, amounting to about half the elaidin, which gradually congeals. It contains water, acetic acid, a volatile oil, an empyreumatic oil, and a good deal of elaidic acid; easily obtained by washing the product in water, and subjecting it to pressure between folds of blotting paper.

The oils of almonds, of filberts, and of acajou, are also converted into elaidin by hyponitrous acid.*

But this test of the purity of olive oil has lost much of its certainty, since it has been shown by Bourdet that castor oil, and by Lescalier that poppy and almond oils, coagulate like olive oil, with nitrate of mercury. Linseed oil and nut oil, on the contrary, are not coagulated by that salt.

Rousseau has proposed another method for testing the purity of olive oil, founded on its being a much worse conductor of electricity than the other vegetable oils. He has contrived a particular instrument for testing olive oil in this way. It consists of a dry galvanic pile, composed of very thin plates of zinc and copper, between which are placed pieces of paper steeped in poppy oil. One of its poles is placed in contact with the earth; the other, by means of a metallic conductor, is placed in contact with a needle feebly magnetic, and very freely suspended. The needle has a small disc at its point. Another disc of the same size is fixed by a metallic thread to the support of the needle. The pole of the pile is brought in communication with this last disc. To use the instrument, the needle is so placed, that in consequence of its polarity, the disc which it carries abuts against the immoveable disc. The electricity which this last disc receives from the pile, is communicated also to the other disc. The consequence is, that the needle disc is repelled. Now, if a layer of oil, of a determined thickness, be placed any where in the electrical circuit, we can see how much it causes the deviation of the needle to diminish. The worse a conductor the oil is, the slower is the deviation in taking place. Rousseau has demonstrated that olive oil conducts electricity 675 times worse than any other vegetable oil. 3 drops of poppy oil added to 177 grains of olive oil, quadruples the conductibility of this last oil.

When such a test is used, we ought to remember that the stearin of animal fat has nearly the same degree of non-conductibility with olive oil.

* Ann. de Chim. et de Phys. l. 394.

Olive oil remains longer than any other vegetable oil without becoming viscid. On this account watchmakers employ it, after having purified it in the following manner:—The oil is put into a crystal bottle along with a plate of lead, and after being corked, it is placed in a window, where it may be exposed to the direct rays of the sun. By little and little, a cheesy matter separates from the oil, and partly swims on its surface, and partly falls to the bottom. The oil loses its colour, and becomes limpid. When the separation of this cheesy matter is at an end, the oil is decanted off, and kept for use.

It appears from the experiments of Fremy, that when olive oil is mixed with half its weight of concentrated sulphuric acid, taking care to prevent all increase of temperature, and the mixture left for 24 hours, there are formed sulpho-margaric acid, sulpho-glyceric acid, and sulpho-oleic acid.*

SECTION II.—OF OIL OF ALMONDS.

This oil is obtained by expression from the fruit of the *amygdalus communis*. It has a light yellow colour, is very fluid, has an agreeable taste, but no smell. Its specific gravity at 60° is about 0·918. When cooled down to 14°, it gives, according to the experiments of Braconnot, 24 per cent. of its weight of stearin, and 76 of elain. The stearin melts at 43°; but the elain does not congeal at the lowest temperature to which it has been exposed. But this statement does not agree with the results obtained by Schubler and Gasserow. According to the last chemist, almond oil contains no stearin at all.

Saussure left oil of sweet almonds for four years in contact with oxygen gas over mercury. The oil absorbed 114·6 times its bulk of the gas, giving out at the same time carbonic acid and hydrogen. The residual gas was 0·3325, or very nearly $\frac{1}{3}$d of the whole, and was composed of

Carbonic acid	96
Hydrogen	20·4
Azotic	18·7
Oxygen	6·9
	142·0†

SECTION III.—OF RAPESEED OIL.

This oil is obtained by expression from the seeds of *brassica rapa* and *napus*. It is yellow, and has a peculiar smell. At the temperature of 28°, it congeals into a yellow mass, and, according to Braconnot, contains 46 parts of stearin, and 54 of elain. The stearin melts at 45°$\frac{1}{2}$. The specific gravity of the oil from *brassica napus* is 0·9128, at 59°, and that from *brassica rapa*, 0·9167. When cooled down to 43°, both of these oils deposit white globules of stearin, and when cooled down a few degrees lower, they assume the consistence of butter.

* Ann. de Chim. et de Phys. lxv. 117. † Ibid. xlix. 228.

Of these plants, the seeds of the brassica rapa yield by far the most oil.

SECTION IV.—OF OIL OF COLZA.

This name is given in France to a superior kind of rapeseed oil, extracted from the seeds of a variety of the *brassica campestris*. It is used in lamps, and has a specific gravity of 0·9136 at 59°. The seeds give 39 per cent. of their weight of oil.

SECTION V.—OF OIL OF MUSTARD.

This oil is expressed from the seeds of the *sinapis alba* and *nigra*. Those of the white mustard give about 36 per cent., and those of the black about 18 per cent. of their weight of oil. It has an amber colour, is destitute of smell, and is thicker than olive oil. The specific gravity of the oil from the black mustard is 0·9170, and that from white mustard 0·9142 at 59°. It dissolves in 4 times its weight of ether, and in 1000 times its weight of alcohol, of 0·833. It makes an excellent soap, and is beginning to be used instead of rapeseed oil.

SECTION VI.—OF TEA OIL.

This oil is much used in China, both for lamps, and as an article of food. It is expressed from the seeds of the *Camellia oleifera* or *sesangua*, and perhaps from other species of that genus of plants. There is no evidence, notwithstanding its name, that it is ever obtained from the seeds of *thea*; though it is probable that these seeds also yield an oil.

It was examined in my laboratory by Dr R. D. Thomson.

The colour of tea oil is a pale yellow, and it is nearly as liquid as olive oil. Its specific gravity is 0·927. It has no sensible smell when pure. It remains fluid at 40°, but at 39° it acquires the consistence of an emulsion. Its temperature may be raised above 660° before it begins to boil, or at least while decomposing. When kept for some time at that temperature it becomes thick, and dark coloured. It burns with a remarkably clear white flame.

It is slightly soluble in sulphuric ether, but insoluble in water and alcohol. Neither nitric nor nitrosulphuric acid act violently on it while cold; but nitric acid, assisted by heat, converts it into a thick yellow fluid, having a peculiar smell. Sulphuric acid immediately blackens it.

It consists of about

Stearin	25
Elain	75
	100

SECTION VII.—OF LAUREL OIL.

The oil from the berries of the *laurus nobilis* cannot be obtained by boiling the bruised berries in water, as has been shown by M.

Menigault;* but it may from the recent berries by pressure. It exists only in the parenchyma, or black pulp which surrounds the cotyledons. M. Subeiran bruised the dry berries, then exposed them to the vapour of water till thoroughly soaked. In this state, subjected rapidly to the press, they yielded laurel oil.†

SECTION VIII.—OF OIL OF ALYSSUM OR MYAGRUM SATIVUM.

This oil is obtained by expression from the seeds of the *alyssum sativum*, a cruciform plant, occasionally observed in England, though hardly a native.

When freed from mucilage it is light-yellow and transparent. Its smell is similar to that of the seeds from which it has been expressed. Its taste also is disagreeable, leaving an aromatic impression in the mouth. It remains liquid though cooled down to 21°; but it congeals when exposed to an intense cold.

It is not a drying oil, and would not answer for painters. But it is excellent for burning in lamps, giving a clear and strong light. It combines with the caustic alkalies, and forms soaps; but they never acquire the consistence of hard soap.‡

DIVISION III.—OF SOLID OILS.

These oils are obtained from plants in a solid state. Some of them have some resemblance to tallow; but the greater number approach nearer to wax.

SECTION I.—BUTTER OF CACAO.

This oil is extracted from the seeds of the *theobroma cacao*, either by expression in a high temperature, or by boiling in water. Butter of cacao is yellowish; but it may be rendered almost colourless by agitating it, while in a state of fusion, in hot water. It has the same smell as the seeds, an agreeable chocolate taste, and the consistence of tallow. Its specific gravity is 0·91. It melts at 122°. It is not liable to become rancid, and on that account is sometimes employed by apothecaries, to prepare those ointments that are likely to be long kept. Lecanu has shown that it approaches nearer to animal fatty matters than to vegetable.‖

According to M. Boutin, when the butter of cacao is treated by alcohol, it yields a neutral crystallizable substance, constituting almost the whole of the butter. It is saponifiable, and when acted on by alkalies, yields a very remarkable new oily acid.§

SECTION II.—OF PALM OIL.

This oil is extracted, according to some, from the *cocos butyraceæ*; according to others, from the *avoira elais*. It has an orange-yellow colour, and the consistence of hog's lard, or butter. It has an

* Jour. de Pharmacie, xxi. 520. † Ibid. p. 524.
‡ Henry, Jour. de Pharmacie, xvi. 71. ‖ Jour. de Pharmacie, xx. 339.
§ Jour. de Pharmacie, xx. 322.

agreeable smell, which has been compared to that of violets. It melts when heated to 99°½. It is said to be composed of

Stearin	31
Elain	69
	100

It becomes readily rancid, and whitens at the same time. It is slightly soluble in alcohol, to which it gives a yellow colour. Its solution in ether is orange. In this country it is used in considerable quantity, in the manufacture of yellow soap, to which it communicates a fine colour, and a degree of softness which makes it more agreeable to washerwomen. It is said to come chiefly from Africa.

M. Frederick Michaelis found that this oil may be deprived of its colour in the following way:—The oil was melted in a copper vessel, and about $\frac{1}{10}$th of its weight of black oxide of manganese in fine powder was put into it, and the whole well mixed together for 8 or 10 minutes. Then a quantity of boiling water, equal to half the weight of the oil, was added, and when the liquid was boiling a quantity of concentrated sulphuric acid was added, amounting to about $\frac{1}{200}$th part of the weight of the oil. The whole was now well stirred, and left to cool. The oil collected on the surface of the water, while the manganese fell to the bottom. The colour of the oil became yellowish-green, and when exposed for some days to the action of the air and light, it became as white as hog's lard.*

SECTION III.—OF TOULOUCOUNA OIL.

This oil is obtained from the fruit of a tree which grows in Senegal, and which has been described by M. Perrottet under the name of *carapa touloucouna*. The seeds are drupas, about the size of a musket bullet. When bruised, and thrown into boiling water, the oil separates and swims on the surface. It concretes, on cooling, into a butyraceous substance, having a yellowish-red colour. Its smell is rancid, and its taste exceedingly bitter and hot, very disagreeable, and exciting vomiting. Yet hogs eat the fruit with impunity. It melts at about 110°. With reagents, it has the properties of a fixed oil.

It is used by the natives to anoint their skins, which effectually prevents the punctures of insects. It has been recommended as a safe medicine for destroying vermin in the heads of children. The substance which occasions the bitter taste has been supposed an alkali, but has not been examined.†

SECTION IV.—OF BUTTER OF NUTMEG.

Obtained by expression from the nutmeg, which is the fruit of the *myristica aromatica*, or *moschata*. It is manufactured in Holland, from which country it is exported in the form of four-sided flat cakes. It consists of two colourless oils similar to tallow: of a fat butyraceous yellow oil, and of a volatile odoriferous oil.

* Poggendorf's Annalen, xxvii. 632. † Virey, Jour. de Pharmacie, xx. 307.

According to Schrader, 16 parts of butter of nutmeg are composed of

Tallow-like oil	7
Yellow oil	$8\frac{1}{3}$
Volatile oil	$\frac{2}{3}$
	16

It is decomposed by cold alcohol and ether, which dissolve the yellow and volatile oils, and leave the tallow, which still retains the odour of nutmeg. To separate the volatile oil from the yellow oil, which remains after the evaporation of the alcohol, it is mixed with water, and the volatile distilled off along with the water.

When butter of nutmeg is boiled with 4 times its weight of alcohol or ether, it is completely dissolved; and during the cooling the tallow precipitates. This butter is employed on the continent in medicine, and always externally. I am not aware of its being employed in this country.

Lecanu has observed that this butter has a greater resemblance to the animal solid oils than to the vegetable.*

It is often imitated by boiling animal fat with powdered nutmeg, and colouring with safflower. But this fraud is easily discovered; for such a mixture will not dissolve in 4 times its weight of boiling alcohol.

That portion of the fruit of the *myristica moschata* called *mace*, contains a *volatile oil* and 2 *fixed oils*. One of these may be extracted by alcohol. On evaporating the alcohol, a red coloured oil remains. The other oil is insoluble in alcohol; but it may be extracted by ether, or obtained by expression. It is yellow. The properties of these oils have been investigated by Bollaert.

SECTION V.—OF COCOA-NUT OIL.

This oil is obtained by expression from the kernel of the cocoa-nut, the well known fruit of the *cocos nucifera*. It is white, and of a pretty hard consistence. Yet it contains both elain and stearin. Of late years it has begun to be employed in considerable quantity in this country as a substitute for tallow in soap-making. It is not easily saponified. The soap made from it in India is rather a mixture of cocoa-nut oil and carbonate of soda. But I have been assured by more than one of the most skilful soap-makers in this country, that they have succeeded in converting it into an excellent soap. The stearin of this oil is used also as a substitute for wax, in the manufacture of candles, for which, on account of the high temperature requisite to fuse it, it answers very well.

SECTION VI.—OF BUTTER OF ILLIPÉ.

This solid oil is extracted from the seeds of the *bassia latifolia*, a tree which grows abundantly in Bengal, and on the Coromandel coast. The oil is probably obtained by boiling the seeds in water.

* Jour. de Pharmacie, xx. 339.

It is solid at the temperature of 73°. It has a light greenish-yellow colour, and an aromatic odour resembling that of olive oil. Its taste is at first sweet, but it leaves an acrid impression in the mouth. It melts at about 82°, and when liquid, has a fine yellow colour. When filtered, it leaves a little brown matter containing tannin. It is scarcely soluble in alcohol of 0·842. But when boiled with that liquid, a little stearin is dissolved, which crystallizes when the liquid cools. It combines readily with the alkalies, and makes an excellent soap. From the soap, abundance of stearic acid may be obtained.*

SECTION VII.—OF BEES' WAX.

Wax differs from the solid vegetable oils in its consistence and in the way in which it combines with alkalies; but it resembles them in so many respects, that an accurate line of separation cannot be drawn.

Bees' wax, though an animal production, agrees so closely with wax from plants, that it would be improper to separate them. It had been the received opinion of naturalists, that the bees collected their wax from the pollen of plants. But Huber has shown that the pollen which the bees carry to their hives, is employed as the food of their larvæ; and that the wax is manufactured by them from sugar. It exudes from the rings in the abdomen of these insects, and is employed by them in constructing the walls of their cells†.

Wax, as it comes from the bee-hive has a yellow colour, and a peculiar smell, both of which are derived from the honey, with which the wax cells are filled. To free it from these impurities, it is melted in water, and cast into thin ribbons which are exposed to the light of the sun, till by the joint action of the light and moisture they are bleached white. Several fusions and exposures are usually required to render it quite white.

Wax, when pure, is snow-white, and without taste and smell. The specific gravity of unbleached wax varies from 0·9600‡ to 0·9650§; that of white wax from 0·8203 to 0·9662.§

It is insoluble in water; nor are its properties altered though kept under that liquid.

When heat is applied to wax, it becomes soft; and at the temperature of 142° if unbleached, or of 155° if bleached,‖ it melts into a colourless transparent fluid, which concretes again, and resumes its former appearance as the temperature diminishes. If the heat be still further increased, the wax boils and evaporates; and if a red heat be applied to the vapour, it takes fire and burns with a bright flame. It is this property which renders wax so useful for making candles.

* O. Henry, Jour. de Pharmacie, xxi. 503.
† This was first ascertained by Mr John Hunter.
‡ Bostock, Nicholson's Jour. iv. 130. § Fabroni, Crell's Annals, 1797, ii. 125.
‖ Bostock, Nicholson's Jour. i. 71.

Wax is scarcely acted on by alcohol when cold, but boiling alcohol dissolves it. This was known to Neumann,* and was verified by Dr Bostock.† Rather more than 20 parts of alcohol are necessary to dissolve 1 part of wax; and as the solution cools, the greater part of the wax precipitates, and the remainder is thrown down by water.‡

Ether has but little action on wax while cold; but when assisted by heat, it takes up about $\frac{1}{20}$th of its weight of it, and lets the greatest part precipitate on cooling.§

Bees' wax contains two distinct kinds of wax, to which John, who first separated them, gave the names of *cerin* and *myricin*. They may be separated from each other by boiling alcohol, which takes up the former, but leaves the latter undissolved.

Cerin he distinguishes by the following properties:—It is soluble in fixed and volatile oils; from the last it precipitates in greasy-looking grains. Insoluble in water, cold alcohol, and ether; soluble in hot alcohol and ether, and precipitating again as the liquids cool. Of the specific gravity 0·969. Of the consistence of wax. Unites with caustic alkalies, and forms a soap.

The cerin, according to John, amounts to 91 per cent.; according to Boudet and Boissenot, to 70 per cent. of the weight of the wax used.

Cerin melts when heated to 143°½. It dissolves in 16 times its weight of boiling alcohol, and in 24 times its weight of cold ether. Hot oil of turpentine dissolves it readily. When cerin is distilled it undergoes decomposition, being converted into margaric acid and empyreumatic oil. But it yields no sebacic or benzoic acid. When assisted by heat it combines readily with sulphuric acid, becomes black, disengages sulphurous acid, and leaves a residue which is soluble in water. Nitric acid has little action on it. When caustic potash is boiled with it, decomposition takes place, margarate of potash is formed and a substance similar to wax.

Boudet and Boissenot,‖ to whom we are indebted for these facts, ascertained that cold alcohol dissolves the margarate of potash and leaves the waxy portion undissolved. To this undissolved portion they have given the name of *cerain*. Weak muriatic acid frees it from the adhering potash. It may then be washed and dried.

It is hard and brittle, melts when heated to 158°, or rather higher, and may be distilled over almost unaltered. It is not soluble in cold alcohol; but a small quantity is dissolved by the assistance of heat. The solution becomes gelatinous on cooling. *Cerain* cannot be converted into soap.¶

* Neumann's Chemistry, p. 331.

† Nicholson's Jour. iv. 133. ‡ Id. Ibid. § Id. Ibid.

‖ Jour. de Pharmacie, xiii. 38.

¶ Chevreul has given the name of *cerin* to a substance which he extracted from cork, and which possessed the following properties:—It is white and in small needles. It does not melt in boiling water, but becomes soft and sinks to the bottom of that liquid; while wax melts at 145° and swims upon the surface of water. When

Myricin, when distilled, passes over almost unaltered. It melts when heated to the temperature of 149°. It requires to dissolve it, 200 times its weight of boiling alcohol of 0·833, and 123 times its weight of anhydrous alcohol; but at the ordinary temperature of the atmosphere it is insoluble in both liquids. When the solution cools the myricin is deposited in flocks. It dissolves in 99 times its weight of cold ether, and is still more soluble in that liquid when hot. It is very soluble in hot oil of turpentine, and is not deposited when the solution cools. It cannot be converted into soap by means of caustic potash.

Wax, while in a state of fusion, dissolves in concentrated sulphuric acid. The compound becomes solid on cooling, but with water it behaves like other compounds of fixed oils and sulphuric acid. Nitric acid decomposes wax with difficulty, oxalic acid being formed. The caustic alkalies convert it into a kind of soap; but the soap which it forms is little soluble in water, and collects on the surface of that liquid like cream. When this cream is melted it constitutes a very hard substance. Punic wax, which the ancients employed in painting *in encausto*, is a soap composed of 20 parts of wax and one of soda.* Its composition was ascertained by Mr Lorgna.†

When boiled with liquid ammonia, it forms a kind of soapy emulsion. As the mixture cools, the greatest part of the compound rises to the surface in the state of white flakes. This soap is scarcely soluble in water.‡

Lavoisier endeavoured to ascertain the composition of bees' wax, by burning a quantity of it in oxygen gas, and determining the proportions of carbonic acid, and water formed. But pneumatic chemistry had not at that time made sufficient progress to enable him to give his experiments the requisite degree of precision. Gay-Lussac and Thenard analyzed it by burning a determinate quantity along with chlorate of potash in a proper vessel, and ascertaining the quantity of carbonic acid formed.§ According to their experiments, 100 parts of wax are composed of

Hydrogen	12·672
Carbon	81·784
Oxygen	5·544

As we are ignorant of the number which represents the weight of an atom of wax, we cannot from this analysis determine the number of atoms of each of these bodies that enter into its composition. But the smallest number of atoms, which will nearly correspond with the proportions obtained by Gay-Lussac and Thenard, are

heated or distilled, it undergoes nearly the same changes as wax. It is rather more soluble in alcohol than wax. Nitric acid gradually dissolves it, and converts a portion of it into oxalic acid. It does not dissolve in an alcoholic solution of potash.(*a*)

* Pliny, lib. xxi. c. 14. † Jour. de Phys. Nov. 1785.
‡ Bostock, Nicholson's Jour. iv. 134. § Recherches Physico-chimiques, ii. 316.

(*a*) Annals of Philosophy, ix. 53.

20 atoms carbon	. = 15	.	82·19
18 atoms hydrogen	. = 2·25	.	12·33
1 atom oxygen	. = 1	.	5·48
39	18·25		100·00

According to this supposition, wax is a compound of 39 atoms, and the weight of an integrant particle of it is 18·25. From the experiments of Chevreul on soaps, there is some reason for believing that the weight of an atom of wax is nearly double the number here assigned, or 36. If this number were accurate, its true constituents would be,

40 atoms carbon	. .	= 30
32 atoms hydrogen	. .	= 4
2 atoms oxygen	. .	= 2
		36

The analysis of Oppermann, by means of oxide of copper, does not deviate very far from that of Lavoisier. He obtained

Carbon	80·18 or 37 atoms	= 27·75	or per cent.	80·14
Hydrogen	14·07 or 39 atoms	= 4·875	— —	14·08
Oxygen	5·75 or 2 atoms	= 2·00	— —	5·78
	100·00*	34·625		100·00

According to Ettling's analysis, cerin, myricin, and cerain, are isomeric bodies, and composed of C^{18} H^{19} O.

But as wax is a mixture of three different substances, it is obvious that no valuable inference can be drawn from these experiments, till they be repeated on each constituent of the wax.

SECTION VIII.—OF MYRTLE WAX.

The myrtle wax of North America is obtained from the *myrica cerifera*. We are indebted to Dr Bostock† and Mr Cadet,‡ for a very exact account of its properties and extraction. The *myrica cerifera* is a shrub which grows abundantly in Louisiana and other parts of North America. It produces a berry about the size of a pepper corn. A very fertile shrub yields nearly seven pounds. The berries are picked off, thrown into a kettle, and covered with water to the depth of about half a foot. The kettle is then boiled, and the berries stirred and squeezed against the sides of the vessel. The wax which they contain is melted out and swims on the surface. It is skimmed off, passed through a cloth, dried, melted again, and cast into cakes. From the observations of Cadet, we learn that the wax forms the outer covering of the berries. The wax thus obtained is of a pale green colour. Its specific gravity is 1·0150. It melts at the temperature of 109°: when strongly heated it burns with a white flame, produces little smoke, and during the combus-

* Ann. de Chim. et de Phys. xlix. 244.

† Nicholson's Jour. iv. 130. ‡ Ann. de Chim. xliv. 160.

tion emits an agreeable aromatic odour. Water does not act upon it. Alcohol, when hot, dissolves $\frac{1}{20}$th of its weight, but lets most of it fall again on cooling. Hot ether dissolves about $\frac{1}{4}$th of its weight; and, when slowly cooled, deposits it in crystalline plates, like spermaceti. The ether acquires a green colour, but the wax becomes nearly white. Oil of turpentine, when assisted by heat, dissolves it sparingly. Alkalies act upon it nearly as on bees' wax. The same remark applies to acids. Sulphuric acid, when assisted by heat, dissolves about $\frac{1}{12}$th of its weight, and is converted into a thick dark-brown mass.* Mr Hatchett has detected a substance precisely similar to myrtle wax in *lac*.† It probably exists in many vegetables.

The wax from the myrica cordifolia, a shrub which grows at the Cape of Good Hope, has been examined by Dr John, and from the characters which he assigns to it, we may consider it as very nearly the same with the myrtle wax of North America.‡

SECTION IX.—OF BRAZIL WAX.

Mr Brande, in 1811, published a chemical examination of wax from Brazil, the produce of an unknown tree in that country.§ It had a greenish colour, was insoluble in water, but soluble in alcohol, ether, and oils. Its specific gravity was 0·980. It melted at the temperature of 206°. It could not be made to form a soap with the fixed alkalies; but answered remarkably well for candles.‖

Brazil wax was analyzed by Oppermann, who obtained

Carbon	71·88 or 6 atoms	= 4·5	or per cent. 72
Hydrogen	12·03 or 6 atoms	= 0·75	— — 12
Oxygen	16·09 or 1 atom	= 1	— — 16
	100·00¶	6·25	100

We see at least, from this analysis, that the constitution of Brazil wax is very different from that of bees' wax.

SECTION X.—OF JAPAN WAX.

A species of wax has been known for some time in India, under the name of Japan wax. A specimen of it was sent me about three years ago from Canton. But no information was communicated respecting the plant from which it was procured.

Its colour is white, with a slight shade of yellow. It is translucent when in thin slices, and is softer than bees' wax. Its specific gravity is 0·97. It melts when heated to 104°, and becomes solid again when cooled down to 93°. It does not stain paper. It is soluble in alcohol and ether when assisted by heat; but on cooling

* Bostock, Nicholson's Jour. iv. 130.

† Analytical Experiments on Lac, Phil. Trans. 1804.

‡ Chimische Untersuchungen, iii. 38.

§ It appears from the observations of M. Virey (Jour de Pharmacie, xx. 112), that the tree yielding this wax, called *carnauba* in Brazil, is the *corypha cerifera* of M. Arruda.

‖ Nicholson's Jour. xxxi. 14. ¶ Ann. de Chim. et de Phys. xlix. 242.

it is deposited from the latter in flocks, while the alcoholic solution, on cooling, becomes thick and opaque. This wax may be combined with soda, and converted into a soap. By this process the wax is converted into a solid acid, not resembling stearic acid, and doubtless peculiar.

From Oppermann's description of an East India wax which he examined, it is obvious that it is the same with the Japan wax. He found it composed of

Carbon	70·00 or 53 atoms	= 39·75	or per cent. 70·09
Hydrogen	12·07 or 55 atoms	= 6·875	— — 12·14
Oxygen	17·93 or 10 atoms	= 10·00	— — 17·77
	100·00*	56·625	100·00

A constitution very different from both that of bees' wax and Brazil wax. But it is obvious from the properties of Japan wax, that it contains, at least, two distinct principles, which would require to be examined separately before any useful conclusions could be drawn.

SECTION XI.—OF FOSSIL WAX OF MOLDAVIA.

Found in Moldavia in masses of considerable size, and presented by Dr Meyer to the Scientific Association at Breslau.

Colour, dark-brown. Composed of two substances, one soluble in alcohol, the other not soluble in oil of turpentine. Magnus analyzed it, and obtained

Carbon	84·6 or 100 atoms	= 75	or per cent. 84·69
Hydrogen	15·3 or 108½ atoms	= 13·5625	— — 15·31
	99·9†	88·5625	100·00

SECTION XII.—COW-TREE WAX, OR GALACTIN.

This substance to which I have given the name of *galactin*, exists in the milk of the cow-tree, or *Galactodendron utile* of Humboldt, a very large tree with leaves like those of the fig, which grows abundantly in the mountains situated on the north-west part of Venezuela, in South America, at a height, according to Humboldt, of nearly 10,000 feet above the level of the sea, and consequently in a climate that cannot differ much from our own.

The juice of this tree, obtained by incision, is known by the name of the *milk of the cow-tree*. By the kindness of Sir William Hooker, Regius Professor of Botany in Glasgow, I had an opportunity, in 1829, of making a few experiments upon this milk, specimens of which had been sent to him by Sir Ralph Woodford, at that time governor of Trinidad.

This liquor was white and opaque, and of the consistence of cream. It had a sour smell, and reddened vegetable blues. Its specific gravity was 1·01242. It contained a small quantity of

* Ann. de Chim. et de Phys. xlix. 240. † Ibid. lv. 217.

acetic acid, to which it owed its acidity. It contains a peculiar substance, which Boussingault and Mariano de Rivero considered as *fibrin;* but I found its characters very similar to those of *cork*. When the milk of the cow-tree is evaporated to dryness by a gentle heat, and the dry residue digested in alcohol, a substance is dissolved, which constitutes by far the most abundant ingredient in the milk. When the alcoholic solution cools it becomes white and opaque, and deposits abundance of snow-white flakes. These, when collected on a filter and dried, constitutes *galactin*. When exposed to a moderate heat it melts into a transparent oil, and on cooling assumes the form of a yellowish-white substance, resembling wax in its appearance.

It is opaque, and has the consistency of wax. At the temperature of 60° it is soft and ductile. At 117° it is still solid, though soft; but at 137° it is fluid. When we heat the white flocks which are deposited from alcohol, they emit abundance of aqueous vapour, and the galactin does not become a transparent liquid till kept for some time at the temperature of 170°, showing that these white flocks consist of water and galactin united together.

Galactin is as tasteless as wax; but when put into the mouth it becomes soft and plastic, and adheres strongly to the teeth. When heated on a platinum spoon it melts, and then froths strongly. When the frothing is at an end, the colour has become brownish-yellow. At 640° it begins to boil, and the vapour burns with a bright yellow flame, giving out much smoke, and leaving behind it a trace of white ashes, which consisted of a mixture of magnesia, and phosphate of lime.

The specific gravity of galactin is 0·969. It dissolves readily in hot alcohol and ether, but is mostly deposited again when these liquids cool. Oil of turpentine dissolves it with facility, and when the oil is cautiously expelled a yellow transparent varnish remains. Olive oil dissolves it with facility, and in considerable quantity before its consistency is sensibly altered.

Galactin does not dissolve in the fixed alkaline leys, and does not seem capable of forming soap. The galactin was digested in caustic potash ley for three days, and boiled for several hours without any appearance of combination. When the ley was allowed to cool, the galactin was found floating on its surface in the state of a solid cake, not sensibly altered in its properties.

Cold nitric acid does not act sensibly on galactin; but when heat is applied, an effervescence takes place, the galactin assumes an orange colour and gradually dissolves. If we pour water into the solution, the galactin separates, apparently little altered except in colour. But if we cautiously evaporate the nitric acid solution to dryness, a yellow, brittle, bitter tasted substance remains, which is soluble both in water and alcohol.

The aqueous solution is not affected by prussiate of potash, or infusion of nutgalls; but with nitrate of lead or nitrate of mercury

it gives a white precipitate; that with the former salt is scanty, with the latter abundant.

The alcoholic solution is yellow and very bitter tasted. Water occasions a precipitate, which is redissolved on agitating the liquid. This solution is precipitated by nitrate of lead, nitrate of mercury, sulphate of zinc, sulphate of manganese, chloride of barium, chloride of strontium, chloride of calcium, and muriate of magnesia.

When galactin is put into concentrated sulphuric acid the liquid assumes a fine brownish-red colour, which gradually deepens. The acid appears green by reflected light, and deep brownish-red by transmitted light. The galactin becomes soft and dark-brown. When heat is applied, effervescence takes place, the galactin is charred, and sulphurous acid disengaged.

When galactin is heated in water it does not float on the surface of that liquid under the form of a transparent oil, as is the case with wax under the same circumstances; but it imbibes a great deal of water, and assumes the form of a white, opaque, viscid matter, not unlike the gluten of wheat in its appearance and adhesiveness, but much more fluid.

The transparent liquid matter which remains when the cold alcoholic solution from the cow-tree milk is distilled off in a retort, possesses most of the characters of galactin, if we except the liquid form under which it appears. It is equally fixed, and equally combustible. It is destitute of taste and smell, stains paper like an oil, and does not combine with potash, but dissolves in nitric and sulphuric acids with the same phenomena as galactin. The two most striking circumstances in which it differs from galactin, are its solubility in cold alcohol, and its liquidity. It does not lose its transparency, but concretes into a kind of varnish like the drying oils.

SECTION XIII.—OF WAX OF CEROXYLON ANDICOLO.

The tree which yields this wax was first described and named by M. Humboldt. It grows on the Andes at Quindiu, in South America, and occupies a zone on these mountains, from the height of 7530 to 9843 feet above the level of the sea. The mean temperature of this zone varies from 52° to 64°½, according to its height. The tree rises to the height of about 164 feet, and its trunk is about 2 feet in diameter. It is, therefore, one of the most majestic palms of the intertropical regions of South America.

The wax of this tree is scraped, or rasped off the bark. When the raspings are heated in water, the wax separates from the impurities with which it was mixed, and swims on the surface of the water without melting. It is made up into balls, and dried by exposure to the sun.

When melted it has a deep yellow colour, slightly translucent, and possesses a good deal of the frangibility of resin. It melts at a temperature a little higher than that of boiling water. When rubbed it becomes strongly electric. It burns with flame, and gives

out a great deal of smoke. Hot alcohol dissolves it readily. On cooling the liquid concretes into a gelatinous mass. Ether dissolves it. By cautious evaporation it may be obtained in the state of silky feathers. Caustic alkalies attack it with difficulty, but gradually dissolve it.

M. Boussingault examined it, and found that it consisted of a *wax*, possessing exactly the characters and constitution of bees' wax, and of a pure *resin*. These two substances being unequally soluble in alcohol, may be separated in the following manner :—

Digest the wax of the tree in a considerable excess of boiling alcohol. On cooling the solution deposits a white gelatinous matter. This is the wax still retaining a little resin, from which it may be freed, by dissolving it two or three times successively in boiling alcohol, and allowing it to fall down when the solution cools.

The cold alcohol retains the resin in solution, but not quite free from wax. Distil off one-third of the alcohol, and let the solution cool: resin is deposited, mixed with a little wax. Continue the evaporation till only one-fourth of the liquid remains: the resin falls down, having a crystalline aspect and a fine white colour. There remains in the alcohol a bitter-tasted substance, which Boussingault considers as a salt of an unknown vegetable alkaloid.

The wax being analyzed by M. Boussingault, he obtained

Carbon	80·28
Hydrogen	13·20
Oxygen	6·52
	100·00

This approaches so near the constitution of bees' wax, as determined by the analysis of Oppermann, given in a preceding Section, that there can be no doubt that the constitution of both is precisely the same.

The resin requires to melt it a temperature higher than that of boiling water. When melted it looks like amber. On concreting it splits in all directions. It is much more soluble in hot than in cold alcohol. It is soluble also in ether, and in the volatile oils.

It was analyzed by M. Boussingault, and found composed of

Carbon	82·19	or 35 atoms =	26·25	or per cent.	82·35
Hydrogen	11·53	or 29 atoms =	3·625	— —	11·37
Oxygen	6·28	or 2 atoms =	2·00	— —	6·28
	100·00*		31·875		100·00

In the preceding Sections an account has been given of the most important of the fixed oils, whether *drying*, *fat*, or *solid*. It would be an endless and useless task to attempt an enumeration of them all. The following table exhibits the names of the principal fixed oils omitted :—

* See Ann. de Chim. et de Phys. lix. 19.

Plants.	Oils.
Corylus avellana.	Nut oil.
Sesamum orientale.	Oil of sesamum.
Guilandina Mohringa.	Oil of behen.
Cucurbita pepo et melapepo.	Cucumber oil.
Fagus sylvatica.	Beech-mast oil.
Helianthus annuus and perennis.	Oil of sunflower.
Nicotiana tabacum et rustica.	Tobacco-seed oil.
Prunus domestica.	Plumkernel oil.
Vitis vinifera.	Grape-seed oil.
Laurus nobilis.	Laurel oil.
Arachis hypogæ.	Ground-nut oil.
Lepidium sativum.	Dittander oil.
Atropa belladonna.	Oil of deadly nightshade.
Myagrum sativum.	Myagrum oil.
Hesperis matronalis.	Rocket oil.
Pinus sylvestris.	Scotch fir-seed oil.
Reseda luteola.	Weld oil.
Euonymus Europeus.	Spindle-tree oil.

CHAPTER VIII.

OF VOLATILE OILS.

But little can be added to the account of volatile oils given in the *Chemistry of Inorganic Bodies* (vol. ii. p. 334). What makes it so difficult to investigate their properties, and to form a correct idea of their chemical constitution, is our not being acquainted with a good mode of obtaining any one of them in a state of purity. They consist of a mixture of two or more oils, differing from each other in their properties and constitution; but as we are not in possession of any method of separating the one completely from the other, experiments made upon the mixture could lead to no accurate or useful result. The best way of proceeding in investigating these bodies, would be to devote a great deal of time to the examination of some one oil. During such an investigation, facts would probably be discovered which might lead to the knowledge of the different oils contained in our mixture, and methods would naturally be suggested of separating them from each other. The volatile oils, from our present knowledge of them, seem divisible into three sets. 1. Those that contain only carbon and hydrogen. They are all lighter than water, and seem to have the property of combining in definite proportions with acids. Hence they are probably bases or analogous to bases. 2. Those that contain carbon, hydrogen, and

oxygen. They are probably as heavy, or heavier than water, and seem to have the property of combining in definite proportions with bases, and are, therefore, analogous to acids. 3. Vesicating oils. They contain sulphur as a constituent, and probably also azote.

We shall attempt to arrange the volatile oils under these three divisions; but from the superficial examination to which most of them have been exposed, an accurate arrangement is at present not to be expected.

DIVISION I.—OF LIGHT VOLATILE OILS.

Six of these oils have been analyzed with sufficient care, namely, oil of turpentine, of lemons, oil of orange flowers, of juniper, of pepper, and of sabine.

SECTION I.—OF OIL OF TURPENTINE.

This oil is obtained from *turpentine*, a viscid, transparent, or translucent semifluid substance, which exudes from various species of the genus *pinus*. The common turpentine of the shops flows by incision from the *pinus abies*, and *pinus sylvestris*. Unverdorben has shown that it is a compound of a *volatile oil* and two resins, to which he has given the names of *pinic* and *silvic acids*. They have been described in the *Chemistry of Inorganic Bodies* (vol. ii. pp. 145 and 149). To obtain the volatile oil, called *oil of turpentine*, the turpentine is mixed with water and distilled. The oil comes over along with the water, and the residue in the still is common *resin* or *rosin*.

The oil of turpentine of commerce is seldom free from *resin*; but it is easy to purify it by mixing it with water, and distilling it over, or *rectifying* it, as the process is called.

When pure it is limpid and colourless, very fluid, and possesses a peculiar smell, rather disagreeable to most persons.

Even when as pure as it can be made by rectification, it reddens vegetable blues, owing to the presence of an acid which Lecanu and Serbat state to be *succinic acid*.* When cooled down to —17° it deposits white crystals of *stearin*. They are heavier than water, and melt when heated to the temperature of about 19°.

Oil of turpentine begins to boil at 313°, but if we continue the ebullition, the temperature rises to 350°, or even higher, showing the presence of more than one volatile oil.

The specific gravity of the vapour of oil of turpentine at the temperature of 313° is, as determined by M. Dumas, 4·83, that of air being unity.† Now,

* I have examined the acid formed during the distillation of oil of turpentine, and found it acetic acid. Its properties are disguised by some resin which it holds in solution. But I saturated it with soda, and fused and filtered the salt of soda formed. It then possessed the well-known characters of acetate of soda, and when distilled with sulphuric acid, gives pure acetic acid.

† Ann. de Chim. et de Phys. lii. 405.

1 volume carbon vapour weighs	0·4133
1 volume hydrogen gas . .	0·0694
	0·4827

and ·4827 × 10 = 4·827. It ought to follow from this that pure oil of turpentine of the boiling point 313°, when all foreign matter is removed, is a compound of

10 volumes carbon vapour
10 volumes hydrogen gas

united together and condensed into 1 volume. Or it ought to be a *decacarbohydrogen*.

Saussure found that oil of turpentine, left for three years and nine months in contact of oxygen gas over mercury, absorbed 127½ times its bulk of that of gas. 118 times its bulk of the gas were absorbed during the first year, and only 9½ times its bulk during the last two years and nine months. The residual gas was 0·78, or more than ¾ths of the whole oxygen gas absorbed, and consisted of

Carbonic acid	66
Hydrogen	20·5
Azote	13·8
Oxygen	0·3
	100·6*

M. Boissenot observed, that when it thus absorbs oxygen, it deposits (when cooled down to 20°) white crystals, the properties of which he examined.†

It has been long known that when oil of turpentine is placed in contact with chlorine gas it catches fire, burning with a dark-red flame, and giving out a great quantity of smoke and soot. This happens when a feather, dipt in oil of turpentine, is plunged into a phial filled with chlorine gas. When a small quantity of chlorine is placed in contact with a large quantity of oil of turpentine it is absorbed, the oil becomes yellow, and acquires consistence.

Iodine is dissolved in great quantity in oil of turpentine. The solution, when saturated with iodine is yellowish-brown. Neither metallic silver nor starch detect the presence of iodine when dissolved in oil of turpentine. But when nitrate of silver or calomel is agitated with the solution, iodide of silver or of mercury is formed. When the solution of iodine in oil of turpentine is distilled, pure oil of turpentine first comes over, and then a brown oil saturated with iodine.

Oil of turpentine absorbs a great quantity of muriatic acid, and forms a crystallized substance, having considerable resemblance to camphor, and, therefore, called *artificial camphor*. It was discovered by M. Kind, apothecary in Eutin, while employed in making

* Ann. de Chim. et de Phys. xlix. 235.
† Jour. de Pharmacie, xii. 214.

a medicine called *liquor orthriticus Pottii*,* about the year 1803. He put a quantity of oil of turpentine into a Woulfe's bottle, and caused a current of muriatic acid gas, expelled from common salt by sulphuric acid, to pass through it. The oil became yellow, then brown, and at last almost solid, from the formation of a great number of crystals in it.† This experiment was repeated by Trommsdorf. He examined the crystals, and found many of their properties similar to those of camphor, though others were different. The Society of Apothecaries in Paris, on being informed of these particulars, appointed Cluzel, Chomet, and Boullay to examine the subject. The result of their labours was published by Boullay.‡ They determined the weight of the crystals yielded by oil of turpentine, and the dose of muriatic acid requisite. They ascertained the properties of the crystals, and endeavoured to explain the way in which they were formed. The experiment of Kind was repeated by Hagen, in 1804,§ and by Gehlen, Schuster, and Pesth, in 1805, chiefly with a view of elucidating the theory of the process.‖ They were also repeated by Thenard with the same object.¶

According to Saussure, 1 volume of oil of turpentine absorbs 163 volumes of muriatic acid gas. The oil ought to be surrounded with ice, otherwise it becomes hot, and allows the gas to escape. When the process is finished, the whole is left at rest for 24 hours. The quantity of crystals formed varies according to the oil of turpentine employed. Oppermann could obtain only crystals corresponding to 30 per cent. of the oil employed;** Trommsdorf obtained 26 per cent. of the oil in the state of artificial camphor; Cluzel obtained 47 per cent.; and Thenard 110 per cent.,†† showing clearly a difference in the oil of turpentine employed.

The crystals, after being formed, may be freed from the uncrystallized liquid, by pressure between folds of blotting paper. They may be still farther purified by solution in alcohol, and repeated crystallizations. Dumas found that they could not be sublimed without losing muriatic acid, and that when rectified off carbonate of lime, they lose a notable portion of that acid.

Thus purified, the compound is white, and crystallized in flexible needles. At the temperature of 68° it is so soft, that it may be kneaded between the fingers. But when cooled down to 52° it is brittle. It has a slight but aromatic taste, and its smell is similar to that of camphor, but not so strong. When heated it melts; and,

* This medicine was made by Pott in this manner :—

2 parts common salt
2 parts oil of turpentine

were mixed together in a retort, and 1 part of concentrated sulphuric acid being added, the whole was distilled over the sand-bath. The liquid that came over was the medicine.

† Trommsdorf's Jour. der Pharmacie, xi. 132, as quoted in Gehlen's Jour. vi. 459.

‡ Ann. de Chim. li. 270. § Gehlen's Jour. ii. 237. ‖ Ibid. vi. 470.

¶ Mem. d'Arcueil, ii. 29.

** Ann. de Chim. et de Phys. xlvii. 225. †† Dumas, Ibid. lii. 404.

if the temperature be raised sufficiently high, it burns with a lively flame, surrounded by a green border.

It does not redden litmus paper, and the alcoholic solution of it is not precipitated by nitrate of silver. But it undergoes decomposition when digested with the alkalies, muriatic acid being abstracted. It is very little soluble in water, though it communicates its peculiar smell to that liquid. Dilute nitric acid does not attack it; but it is dissolved by concentrated nitric acid. It is decomposed when the alcoholic solution is distilled five or six times off hydrate of lime.

Artificial camphor, prepared by M. Oppermann with great care at Strasburg, was found by him to be composed of

Carbon	72·81	or 25 atoms	= 18·75
Hydrogen	8·98	or 18 atoms	= 2·25
Muriatic acid	8 1·21	or 1 atom	= 4·625
	100·00*		25·625

But M. Dumas has shown that Oppermann's mode of purifying the artificial camphor, by subliming it off carbonate of lime, deprived it of a portion of its muriatic acid. He purified it by pressure between folds of blotting paper, and repeated crystallizations from alcohol. Thus prepared, it was composed of

Carbon	69·32	or 20 atoms	= 15
Hydrogen	9·88	or 17 atoms	= 2·125
Chlorine	20·80	or 1 atom	= 4·5
	100		21·625

Or

20 atoms carbon . .	= 15
16 atoms hydrogen . .	= 2
1 atom muriatic acid .	= 4·625
	21·625†

Oppermann, when he decomposed artificial camphor, obtained a clear, transparent oil, not at all similar to oil of turpentine, and which he distinguished by the name of *dadyl*. It became solid and white at the temperature of 50°, but again melted when exposed to the heat of the hand. Sulphuric acid changed it into a brown resinous matter. Fuming nitric acid and acetic acid did not dissolve nor decompose it, showing that it differed completely from common oil of turpentine. Ether, alcohol, and bisulphuret of carbon dissolved it. It was subjected to an analysis, and found composed of

Carbon	88·48
Hydrogen	11·52
	100·00

* Ann. de Chim. et de Phys. xlvii. 237. † Ibid. lii. 402.

This is equivalent to

10 atoms carbon	= 7·5	or per cent. 88·24
8 atoms hydrogen	= 1·0	— — 11·76
	8·5	100·00

Dumas found that the base which he abstracted from artificial camphor, by freeing it completely from muriatic acid, was a liquid which, when properly purified, presented all the characters of oil of turpentine. It boiled when heated to 313°; and the specific gravity of its vapour was 4·83. He subjected it to analysis, and obtained sensibly the same composition as Oppermann had done, namely,

10 atoms carbon . . .	= 7·5
8 atoms hydrogen . . .	= 1
	8·5

Oil of turpentine obtained by Blanchet and Sell, by distilling turpentine from the Vosges with water, and then rectifying it from chloride of calcium, had a specific gravity of 0·880, and its boiling point was 311°. It was composed of

Carbon	88·54
Hydrogen	11·52
	100·06

Numbers which almost coincide with the preceding analysis.*

From the analysis of artificial camphor, it is not unlikely that pure oil of turpentine is C^{20} H^{16}.

It follows clearly from these experiments, not merely that oil of turpentine varies in its composition, but that it contains two distinct substances, both of which are capable of forming artificial camphor. Doubtless the liquid obtained by Dumas, which boils at 313°, is what constitutes the most volatile part of oil of turpentine, and that portion to which it is indebted for its peculiar smell. Dumas has distinguished it by the name of *camphene*, conceiving it to be one of a numerous class of bodies which exists in volatile oils, capable of uniting with muriatic acid. It is evident, from his experiments, that it contains no oxygen, but is merely a compound of carbon and hydrogen. The result of his analysis is 10 atoms carbon + 8 atoms hydrogen. The density of the vapour does not agree with this supposition. Could we depend upon the accurate determination of this density, we would be obliged to admit that the oil is a compound of

10 atoms carbon . . .	7·5
10 atoms hydrogen . . .	1·25
	8·75

But as the analysis by means of oxide of copper, when rightly conducted, is susceptible of much greater precision than the method of

* Jour. de Pharmacie, xx. 225; or Annalen der Pharmacie, vi. 263.

taking the specific gravity of vapours, we must abide by the results of that analysis, and consider it as a compound of

10 atoms carbon	7·5 or 20 carbon	=	15
8 atoms hydrogen	1 16 hydrogen	=	2
	8·5		17

Besides the two liquids in oil of turpentine, which form artificial camphor, it is obvious that it must contain another liquid into which oxygen enters as a constituent, otherwise it could not, as it is well known to do, change potassium so rapidly into potash.

Artificial camphor is obviously a compound of

1 atom oil of turpentine of 313°	= 8·5
1 atom muriatic acid . .	= 4·625
	13·125

According to Couerbe, the volatile oils are composed of an oil destitute of smell, and of one or more commonly two oils, to which the smell and taste of the oil is owing. These may be removed by means of a fixed alkali, and then the inodorous oil may be procured in a separate state. He assures us that he has separated an inodorous oil from oil of turpentine.* If this be so, it constitutes another substance in oil of turpentine. For it is obvious, that neither the *camphene* of Dumas, nor the solid matter obtained by Oppermann, possess the characters assigned by Couerbe to his oil.

Oil of turpentine then is a compound of at least four or five different substances, some of which may be obtained in a separate state by the processes above indicated.

MM. Boissenot and Perrot obtained from oil of turpentine, long exposed to the air, a transparent solid matter in rectangular prisms. It had neither taste nor smell; fused at 302°, and was volatilized below 311°. It is insoluble in cold, but very soluble in hot water. The same remark applies to ether. Nitric acid dissolves it cold without alteration, when hot decomposes it. Sulphuric acid dissolves it, and assumes a fine red colour. Acetic acid dissolves it cold; muriatic acid only when heated. Concentrated solutions of potash and soda do not act on it, but diluted solutions dissolve it.†

It was analyzed by MM. Dumas and Peligot, who obtained

Carbon	62·99 or 20 atoms	= 15	or per cent.		63·16
Hydrogen	11·41 or 22 atoms	= 2·75	—	—	11·58
Oxygen	25·60 or 6 atoms	= 6	—	—	25·26
	100·00	23·75			100·00‡

A similar substance was observed in the oil from *ocymum basilicum*, and in the essential oil of *cardomum minus*.

What is called oil of *templin* in Switzerland, is obtained from the *pinus mugho*, and appears, from the experiments of MM. Blanchet

* Ann. de Chim. et de Phys. liii. 219. † Ibid. xxxii. 442. ‡ Ibid. lvii. 334.

and Sell, to be identical with oil of turpentine. They found its properties similar, and its constituents,

Carbon	88·07
Hydrogen	11·62
	99·69*

obviously the same as those of oil of turpentine.

SECTION II.—OF OIL OF LEMONS.

This oil is extracted from the rind of the lemon, the well known fruit of the *citrus medica*, or *lemon tree*. It is usually obtained by expression, and comes to us from the south of Europe under the name of *essence of lemons*.

It is limpid, and has a light-yellow colour, which deepens by age. But when distilled over with water, if we stop the process when $\frac{2}{3}$ds of the liquid has passed over, we obtain a colourless oil, having a specific gravity of 0·847 at the temperature of 71°$\frac{1}{2}$, as determined by Saussure.† It does not become solid though cooled down to 4°.

This oil has an agreeable odour, similar to that of lemons. Its boiling point has not been determined; but in all probability it is nearly the same as that of oil of turpentine, or 313°.

It dissolves in all proportions in absolute alcohol. But spirit of wine, of the specific gravity 0·837, dissolves only 14 per cent. of it at the temperature of 60°.

Blanchet and Sell analyzed oil of lemons, and found its constituents to be

Carbon	86·73
Hydrogen	11·47
	98·20‡

This approaches

10 atoms carbon	= 7·5	or per cent.	88·23
8 atoms hydrogen	= 1·0	— —	11·77
	8·5		100·00

We have three other analyses of this oil, namely,

	Saussure.	Hermann.	Dumas.
Carbon	86·879	88·5	88·45
Hydrogen	12·326	11·5	11·46
	99·205	100	99·91

showing together that its constitution is similar to that of oil of turpentine.

Thenard first observed that this oil absorbs muriatic acid gas, and forms a crystalline substance similar to the artificial camphor

* Jour. de Pharmacie, xx. 226. † Ann. de Chim. et de Phys. xiii. 263.
‡ Ann. der Pharmacie, vi. 281.

made in the same way with oil of turpentine.* The nature of the combination was afterwards investigated by Saussure. He found that at the temperature of 680°, oil of lemons absorbed 286 times its bulk of muriatic acid gas. During the absorption the oil becomes hot, and assumes a yellow colour, and increases about $\frac{1}{3}$th in bulk, and about 0·49 in weight. At the temperature of 54° it concretes into a mass of crystals, which may be purified by pressure between folds of blotting paper.†

The crystals are flat rectangular four-sided prisms. They have a weak odour, resembling that of thyme. They are heavier than water, and do not catch fire, unless they be strongly heated. They do not undergo decomposition when exposed to the atmosphere, and their volatility is not great. However, when long kept in a phial, they rise and are deposited in quadrangular prisms upon the sides of the glass. When heated to 106°, these crystals melt, and on cooling concrete into a crystalline mass, which is very brilliant.

This compound may be distilled over without any striking decomposition, if we apply the heat rapidly; but in a long-continued gentle heat decomposition takes place.

It is insoluble in water, and has no perceptible taste. Alcohol of 0·806 dissolves, at the ordinary temperature of the atmosphere, the 16th part of its weight of it. But the solution is precipitated in crystals by the addition of water.

It is not decomposed by cold caustic potash. Concentrated sulphuric acid causes the disengagement of muriatic acid without the formation of any sulphurous acid, and slowly dissolves the oily base of the compound, assuming, at the same time, a yellow colour. Muriatic acid has no action on it whatever. Nitric acid of 1·39, applied cold, scarcely produces any sensible effervescence. 1 part of *muriate of citrene* (as this substance has been called by Dumas‡) took 15 days to dissolve in 42 parts of nitric acid, of the specific gravity, 1·235. The nitrate of silver being mixed in excess with that solution, occasioned an abundant precipitate of chloride of silver. The deposition continued to take place for several days.§

This compound has been lately analyzed with great care by Dumas,‖ and by Blanchet and Sell.¶ They obtained from crystals, purified by compression, and repeated crystallizations in alcohol,

	Dumas.	Blanchet and Sell.				
Carbon	58·025	57·49	or 10 atoms =	7·5	or per cent.	57·14
Hydrogen	8·625	8·54	or 9 atoms =	1·125	— —	8·57
Chlorine	33·350	33.81	or 1 atom =	4·5	— —	34·29
	100·000	99·84		13·125		100

This is equivalent to

* Mem. D'Arcueil, ii. 32. † Ann. de Chim. et de Phys. xiii. 265.
‡ Ibid. lii. 49. § Ibid. xiii. 268. ‖ Ibid. lii. 405.
¶ Ann. der Pharmacie, vi. 284.

10 atoms carbon	=	7·5	or per cent.	57·14
8 atoms hydrogen	=	1	— —	7·63
1 atom muriatic acid	=	4·625	— —	35·23
		13·125		100·00

Thus the composition of muriate of citrene is precisely the same as that of muriate of camphene, namely,

1 atom citrene . . .	= 8·5
1 atom muriatic acid . .	= 4·625
	13·125

Dumas found that the whole of oil of lemons could be converted into muriate of citrene.

The base of this salt, or the *citrene*, may be obtained by means of potash or lime. When we distil repeatedly, we obtain a limpid colourless oil, possessing all the characters of oil of lemons. Dumas subjected it to analysis, and obtained

Carbon . .	87·05	or 10·06	atoms
Hydrogen .	11·53	or 8	atoms
	98·58		

The analysis of Blanchet and Sell* gave

Carbon	87·25
Hydrogen . . .	11·52
	98·77

Thus it appears that the citrene, or pure oil of lemons, as we must consider it, is exactly similar, in its compositions, to camphene or pure oil of turpentine. As Dumas has not given us the specific gravity of the vapour of oil of lemons, we cannot compare the above analysis with the theoretic result from specific gravity.

Saussure found that oil of lemons, left in contact with oxygen gas over mercury for fifteen months, absorbed 143$\frac{1}{3}$ times its volume of that gas. The residual gas amounted to 0·2145, or rather more than $\frac{1}{5}$th of the oxygen gas absorbed. It was composed of

Carbonic acid . .	61·9	volumes.
Azotic . . .	25·2	—
Oxygen . . .	16·8	—
Hydrogen . . .	10·8	—
	114·7†	

SECTION III.—OF ORANGE-FLOWER OIL.

This oil, called *neroli* in the south of Europe, is extracted by the distillation of the flowers of the *citrus aurantium*, or orange tree, together with water. When newly prepared, it is yellow; but by exposure to the sun, it may be made to assume a yellowish-red

* Ann. der Pharmacie, vi. 286. † Ann. de Chim. et de Phys. xlix. 234.

colour. It is very liquid, lighter than water, and possesses the agreeable odour which distinguishes the orange-tree flowers.

The aqueous solution of this oil, under the name of *orange-flower water*, is used as an aromatic. It is obtained either by dissolving the oil in water, or by distilling the flowers along with water. During this distillation another substance passes over along with the oil, which possesses the property of assuming a red colour, when a few drops of sulphuric acid are added to the liquid. This property enables us to ascertain whether orange-flower water has been formed by dissolving the oil in water, or by distilling the flowers. In the former case, sulphuric acid does not render the liquid red: in the latter case it does.

M. Plisson has shown that this oil, like the preceding, contains at least two different substances. He obtained a solid constituent from it, by adding alcohol, of the specific gravity 0·842 to the oil, till the whole was dissolved. A white precipitate begins to appear, and continues for some time to fall. Indeed the alcoholic solution continues for days to deposit whites scales. This precipitate is purified by washing it in alcohol, dissolving it in ether, and precipitating it a second time by means of alcohol. When the ethereal solution is evaporated spontaneously, we obtain the white matter in crystals. The recent oil furnishes about 1 per cent. of this substance; but the quantity diminishes with the age of the oil.

The crystals of this substance are in scales, lustre pearly, tasteless, and destitute of smell, and having no action on vegetable blues. They soften at 122°, and melt at 131°. On cooling they concrete into a translucent mass, having the aspect and fracture of wax. The specific gravity in this state, at 63°½, is 0·913. *In vacuo*, it may be volatilized easily without alteration.

It is insoluble in water; but dissolves in 60 times its weight of boiling alcohol, of the specific gravity 0·800, and is deposited in scales when the solution cools. It dissolves readily in hot oil of turpentine, and is deposited when the solution cools in transparent plates. Sulphuric ether is its best solvent. Sulphuric acid does not attack it while cold; but when heated, sulphurous acid is formed, and the white substance is charred. Nitric acid seems to have no action on it, even when assisted by heat; the same remark applies to muriatic acid.

M. Plisson could not succeed in converting this substance into a soap. He considers it as one of the constituents of oil of orange flowers, and has given it the name of *aurade;* considering it as a fatty substance analagous to *ambrein*, *myricin*, *ethal*, and *cerain*, all of which are fatty bodies, unalterable by alcohol, and not capable of being converted into soap by means of potash.*

Its constituents, according to the analysis of Henry and Plisson, are

* Ann. de Chim. et de Phys. xl. 83.

Carbon	83·76
Hydrogen	15·0892
Oxygen	1·1508
	100·0000*

This (if the oxygen be not accidental) gives the following formula:

97 atoms carbon	= 72·75
105 atoms hydrogen	= 13·125
1 atom oxygen	= 1·00
	86·875

SECTION IV.—OF JUNIPER BERRY OIL.

This oil is obtained by distilling pounded juniper berries along with water. It is limpid and colourless, or having a slight shade of yellow. Its specific gravity is 0·911. It has the well known smell and taste of juniper berries. It is very little soluble in water, and scarcely more so in alcohol. Spirits impregnated with it constitute the well known *Geneva* of the Dutch. The distillers at Schiedam were formerly in the habit of carrying over annually a ship load of juniper berries from Inverness, for the use of their distilleries.

Oil of juniper is employed in medicine, and considered as a diuretic. It is said sometimes to be adulterated by oil of turpentine. This fraud may be easily detected by taking the specific gravity of the oil, which is lighter than usual, when mixed with oil of turpentine.

M. Blanchet has extracted two different oils from juniper berries.† 8 pounds of unripe juniper berries, distilled with salt water, furnished 2 ounces of oil, which, by cautious redistillation, was separated into a more and a less volatile oil. The same quantity of ripe berries furnished only half an ounce of oil, which was all of the less volatile variety.

The more volatile oil is colourless. Has the smell of juniper berries, with something resembling that of pine oil. When it is shaken with salt water, a crystallized substance precipitates, probably a hydrate of the oil. When a drop of this oil, rectified on quicklime, and freed from water by chloride of calcium, is let fall upon paper, it is almost immediately converted into a resin. Its specific gravity is 0·8392, and it boils at 311°. It dissolves with difficulty in alcohol of 0·85. When mixed with its own weight of anhydrous alcohol, it forms a transparent liquid, from which, however, it gradually separates. It dissolves in ether, and may be mixed in all proportions with ether, free from alcohol.

It was analyzed by Blanchet,‡ who obtained

Carbon	87·21
Hydrogen	11·52
	98·73

* Jour. de Pharmacie, xvii. 450. † Poggendorf's Annalen, xxxiii. 59.
‡ Ann. der Pharm. vii. 166.

The less volatile oil cannot be obtained colourless. Its specific gravity is 0·8784, and it boils at 401°. It dissolves with difficulty in alcohol of 0·85, and requires 8 times its weight of anhydrous alcohol to dissolve it. It dissolves in ether, does not effervesce with iodine, and is not decomposed by potassium.

It was analyzed by Blanchet, and found isomeric with the more volatile oil.

These two oils have the same composition as oil of turpentine; namely, C^{10} H^{8}.

When caustic potash is added to the water distilled over with these oils, a crystallized substance falls, which is a hydrate of the oil, composed of C^{10} H^{8} + 2 atoms water.

When a little iodine is added to a few drops of oil of juniper, much heat is evolved, and yellowish-violet vapours are exhaled. The residue, when cold, was fluid, had a yellowish-brown colour, and retained the smell of the oil.*

SECTION V.—OF OIL OF PEPPER.

This oil is extracted from common pepper (*piper nigrum*). When newly extracted it is limpid and colourless; but becomes gradually yellow. It is lighter than water. It has the smell, but not the taste of pepper.

It is composed, according to the analysis of Dumas, of

Carbon	87·9 or 10 atoms	= 7·5	or per cent.	88·23
Hydrogen	11·7 or 8 atoms	= 1	— —	11·77
	99·6†	8·5		100·00

So that its constitution agrees with that of oil of turpentine and oil of lemons.

SECTION VI.—OF OIL OF SABINE.

It is obtained from the leaves of the *juniperus sabina*. Limpid. Has the odour and flavour of sabine. This plant furnishes a great deal of oil. Sabine owes its diuretic properties to this oil.

It was analyzed by Dumas, and found to be a compound of

10 atoms carbon	= 7·5	or per cent.	88·23
8 atoms hydrogen	= 1·0	— —	11·77
	8·5		100‡

Iodine acts violently on it. Much heat is evolved, and yellowish and violet vapours given out. A resinous mass, of a deep brownish-red, remained.§

* Hashoff, Jour. de Pharmacie, xvii. 112. It appears from the experiments of M. Bonastre, that when the rasped wood of the *Juniperus Virginiana* is distilled with water, a volatile oil is obtained, which is liquid (after being filtered), but thick and glutinous. It yields crystals when cooled down, or when a crystal is put into it. See Jour. de Pharmacie, xxiii. 177.

† Jour. de Pharmacie, xxi. 192. ‡ Ibid. xxi. 193.

§ Hashoff, Jour. de Pharmacie, xvii. 112.

SECTION VI.—OF OIL OF THUYA OCCIDENTALIS.

The *thuya occcidentalis* is a native of Canada, and has been long cultivated in our shrubbries. M. Bonastre extracted a volatile oil from it, by distilling its leaves along with water.* This oil is liquid, transparent, lighter than water, and has a light yellow colour, with a shade of green. When rectified it becomes lighter, but does not lose its colour. Its taste is strong, analagous to that of camphor, and its smell resembles that of tansey. Concentrated sulphuric acid renders it brown, and chars it. Nitric acid deepens its colour, but does not set it on fire. Muriatic acid renders it muddy, and increases its odour. Acetic acid dissolves about $\frac{1}{10}$th of its weight of it.

DIVISION II.—OF VOLATILE OILS CONTAINING OXYGEN.

As only a very few of these oils have been subjected to a chemical analysis, the greater number of those which occur in this division have been placed in it merely from analogy. Several of them no doubt belong to the first division.

SECTION I.—OF OIL OF CLOVES.

This oil is extracted from the unripe fruit of the *caryophyllus aromaticus*, called by modern botanists *eugenia caryophyllata*, or clove tree, a plant which is a native of the islands in the Indian Ocean. It is colourless or light yellow when fresh, but the colour deepens by keeping, and becomes at last a dark brown. It has the well known smell of cloves, and a hot disagreeable taste. Its specific gravity, according to Dr Lewis, is 1·034; but Bonastre, who has lately subjected this oil to numerous experiments,† found it to vary from 1·055 to 1·061.

M. Ettling found it a mixture of two oils, easily separated by mixing the oil with potash ley and distilling. A colourless oil passes over, having a specific gravity of 0·918, incapable of combining with bases, but absorbing muriatic acid in great abundance, without yielding a crystalline compound. It is composed of 10 atoms carbon, and 8 atoms hydrogen, without any oxygen.

When the residue is mixed with an excess of phosphoric or sulphuric acid, the other oil passes over. It reddens litmus paper, and possesses the characters of an acid. It is colourless, has a specific gravity of 1·079, and boils at 469°½.‡

It is one of the least volatile, and most difficult to distil of all the volatile oils. M. Bonastre found, that when oil of cloves and oil of turpentine are mixed together, the latter may be completely separated by a graduated distillation.§ When kept for a certain time, it deposits a solid crystalline matter. Seemingly the same substance is obtained when pounded cloves are boiled in alcohol, and the solu-

* Jour. de Pharmacie, xi. 156. † Ann. de Chim. et de Phys. xxxv. 274.
‡ Poggendorf's Annalen, xxxi. 526. § Jour. de Pharmacie, xiv. 579.

tion is filtered while hot. On cooling it deposits brilliant white crystals, which have neither taste nor smell. They are soluble in ether, but insoluble in alkalies, and incapable of forming soap. When gently heated they sublime unaltered.

Oil of cloves is soluble in alcohol, ether, and concentrated acetic acid. It may be exposed for hours to a cold of 4°, without becoming solid. It absorbs chlorine gas, and becomes first green, and then brown. In this state it contains muriatic acid, and is partially converted into resin. Nitric acid gives it a red colour, and when the mixture is heated oxalic acid is formed. If we mix it with about $\frac{1}{3}$d of its weight of sulphuric acid, added by little and little, to prevent the oil from becoming hot, we obtain an acid liquid, at the bottom of which we find a purple-coloured resin. This resin, after being washed, is hard and brittle. Alcohol dissolves it, assuming a red colour, and water throws down the resin from the solution, having a blood-red colour. It dissolves also in ether.

When the acid liquid is diluted with water, a dark-coloured oil precipitates, which, when distilled with water, gives a limpid volatile oil, leaving a portion of purple-coloured resin.

When we agitate together a concentrated solution of caustic soda and oil of cloves in equal volumes, the mixture speedily thickens, and fine laminated crystals are deposited. If we now pour water into the mixture, and distil, a small quantity of a volatile oil passes over, which differs from oil of cloves by its smell and its chemical properties. During the cooling, the liquid remaining in the retort deposits a great number of crystalline needles, which, when separated by expression from the alkaline liquid, are nearly destitute of smell, but have a taste at once alkaline, and burning like that of the oil.

These crystals dissolve in from 10 to 12 times their weight of cold water.

The oil of cloves combines in a similar manner with other bases, so as to show decidedly the characters of an acid body. The following are the results which Bonastre obtained:—

2. *Ammoniated clove oil.* When a current of ammoniacal gas is passed through the oil, it is absorbed, and the oil becomes inspissated. This matter remains solid as long as the vessel containing it is corked, but when opened it becomes liquid. It solidifies again when we cork the vessel, and this phenomenon may be repeated at pleasure.*

If we agitate oil of cloves with liquid ammonia, a granular deep-coloured matter is deposited, which does not dissolve, and allows the ammonia to escape when left exposed to the air.

3. *Clove-oil potash.* When clove oil is treated by potash in the same way as has been described by soda, a combination takes place, which separates in white plates, having the taste of the oil, and reacting strongly as an alkali. When dried at 212°, they contain between 11·69 and 12 per cent. of potash. These crystals may be dissolved in water, and crystallized a second time, though they are

* Karls, Poggendorf's Annalen, x. 609.

partly decomposed during the process. Nitric acid gives them a fine red colour. With water, alcohol, and ether, they behave as clove-oil soda.

4. *Clove-oil barytes.* When clove oil is heated, with barytes water, a combination takes place, especially if assisted by heat. On cooling, small crystalline needles are deposited. These crystals have a pearly lustre. They have the taste and the smell of clove oil. They are composed of

Barytes, ...	30·3
Clove oil, ...	69·7
	100·0

If we suppose the barytes saturated in this compound, the atomic weight of clove oil would be 21·85.

Nitric acid gives this compound a yellow colour. With the per-salts of iron it strikes a lilac or violet colour. It is somewhat soluble in cold, and much more soluble in hot water. When decomposed by sulphuric acid, it leaves a brown-coloured clove oil, which after being distilled over gives a red colour to litmus paper.

5. *Clove-oil strontian* is made in the same way, and possesses properties similar to those of clove-oil barytes.

6. *Clove-oil lime.* When 1 part of oil, and 2 parts lime, are boiled together in water, we obtain a greenish-white liquid, not becoming muddy on cooling. By evaporation we obtain clove-oil lime in the state of a yellow crust, which must be removed from time to time if we wish to continue the evaporation. It has a weak taste of clove oil, when treated with nitric acid becomes safron-yellow. With sulphuric acid it effervesces and becomes wine-red. It is soluble in 235 times its weight of water.

7. *Clove-oil magnesia.* Calcined magnesia, when digested with clove oil, forms a white hard compound, not crystallizable, and completely insoluble in water, whether cold or hot.

8. *Clove-oil iron.* When clove-oil potash or soda is boiled with sulphate of iron, a blue-coloured magma is produced. With the sulphated peroxide of iron the precipitate is red, but becomes gradually violet and then blue.

9. *Clove-oil lead.* When protoxide of lead and clove oil are boiled together in water, renewing the liquid as it evaporates, a yellow-coloured adhesive mass is obtained, which is insoluble in water. When dried in the open air, it becomes friable. A similar compound is formed when clove oil, potash and acetate of lead are digested together.

10. *Clove-oil copper.* This compound is precipitated when *clove-oil soda* and sulphate of copper are mixed together. It is at first brown, but by half an hour's boiling becomes sky-blue or verdigris-green.*

The marked acid properties of this oil induced M. Dumas to make a set of experiments to determine its composition. He was supplied with the pure oil of cloves by M. Bonastre, and in order

* Bonastre, Ann. de Chim. et de Phys. xxxv. 274.

to deprive it of water, it was rectified over chloride of calcium. His attempts to determine its atomic weight by combining it with potash or soda were unsuccessful. The crystals always retained a great quantity of uncombined alkali from which it was impossible to free them. But he found no difficulty in saturating the oil with ammoniacal gas. 0·653 grammes of this oil absorbed 83 cubic centimetres of ammoniacal gas at the temperature of 32°, and under a pressure of 29·92 inches of mercury. Hence it follows that 100 parts of the oil absorb (at the temperature of 60°) 9·7 parts of ammonia, so that ammoniated clove oil is composed of

Clove oil,	100	or 21·9
Ammonia,	9·7	or 2·125

This would make the atomic weight of clove oil 21·9, or very nearly 22.

Dumas analyzed clove oil by means of oxide of copper, and obtained

Carbon	69·93 or 20 atoms	= 15	or per cent.	69·36
Hydrogen	7·89 or 13 atoms	= 1·625	— —	7·52
Oxygen	22·18 or 5 atoms	= 5	— —	23·12
	100·00*	21·625		100

Ettling subjected to analysis the acid oil extracted from cloves, and obtained

Carbon	71·64 or 24 atoms	= 18	or per cent.	72·36
Hydrogen	7·44 or 15 atoms	= 1·875	— —	7·54
Oxygen	20·92 or 5 atoms	= 5	— —	20·10
	100·00	24·875		100·00

M. Ettling endeavoured to find the atomic weight of this oil by combining it with bases. But the experiment was attended with unexpected difficulties. The best result was clove-oil lead composed of

Acid	37·39 or 25·24
Oxide of lead	62·61 or 42 = 14 × 3
	100·00

Supposing the salt to be a trisclove-oil lead, the atomic weight would be 25·24.†

It appears from this analysis that oil of cloves differs from oil of turpentine, oil of lemons, and oil of orange flowers, all of which are lighter than water by containing a notable quantity of oxygen. Dumas assures us that a similar constitution belongs to all those volatile oils which are heavier than water. They all possess acid properties, and doubtless these acid properties they owe to the oxygen which they contain. Oil of turpentine, and oil of lemons, on the other hand, that portion of them at least which combines with muriatic acid, contain no oxygen. Hence it seems reasonable to conclude that those volatile oils which possess the characters of bases, and which are all lighter than water, contain no oxygen; but are simple compounds of carbon and hydrogen.

* Ann. de Chim. et de Phys. liii. 164. † Poggendorf's Annalen, xxxi. 528.

M. Bonastre observed a crystallized substance in oil of cloves.* It was in thin, white, pearly, transparent scales. When kept it gradually assumed a yellow colour. It is very soluble in alcohol and ether. It has the smell and the taste of cloves, but far weaker than clove oil. When placed in contact with nitric acid, it immediately assumes a red colour. It was analyzed by Dumas who found it to be clove oil combined with an atom of water, or an hydrate of clove oil. Or its composition may be represented by the formula C^{20} H^{13} O^5 + HO.

Bonastre proposes to distinguish this substance by the name of *eugenin*. But the term *hydrate of clove oil* would be better, as it would recal to mind its composition.

SECTION II.—OF OIL OF CINNAMON.

Described under cinnamic acid in the Chapter on acids.

SECTION III.—OF VOLATILE OIL OF BITTER ALMONDS.

This oil may be obtained by distilling bitter almonds with water. When the fixed oil of bitter almonds is obtained by expression, without the application of heat, it contains no trace of the volatile oil. Reduce the matter of bitter almonds thus freed from fixed oil to a coarse powder, place it loosely upon a seirce at the top of an alembic containing water, and distil off the water; the vapour of the water passing through the marc of the almonds, carries along with it the volatile oil. The first portions of water that pass over are limpid, and the oil which they contain falls to the bottom of the liquid. The subsequent portions of water are milky and less charged with oil. When the water begins to distil over limpid and colourless, it is a proof that the oil has all been volatillized.† Neither the oil nor the water reddens vegetable blues.

The oil which comes over first has so strong an odour that in this respect it has a greater resemblance to cyanogen than to hydrocyanic acid. The first limpid portions of water that come over contain a good deal of the oil in solution.

Oil of bitter almonds has a golden-yellow colour, is heavier than water, and has a strong but agreeable odour of hydrocyanic acid. When exposed to the air, it absorbs oxygen, and deposits a great number of white crystals.‡ Robiquet found that this oil is a compound or mixture of two different oils. The one, which comes first over is more volatile and contains hydrocyanic acid, which renders it very poisonous. The other oil, which comes over last, is not poisonous, absorbs oxygen from the air, and assumes a crystalline form.§

Vogel showed that oil of bitter almonds contains abundance of

* Jour. de Pharmacie, xx. 565.

† Robiquet and Boutron-Charlard, Ann. de Chim. et de Phys. xliv. 364.

‡ Is it not likely that these crystals are the *amygdalic acid*, described in a former Chapter of this work? Stange considered them as *benzoic acid*, to which the amygdalic has a striking resemblance.

§ Ann. de Chim. et de Phys. xxi. 250.

hydrocyanic acid.* If we dissolve 100 parts of this oil in alcohol, and mix the liquid with an alcoholic solution of potash, and then throw down the oil by water, we obtain, according to Schrader, a quantity of cyanodide of potassium capable of forming 22½ parts of Prussian-blue. Having kept the oil for three years, and then subjected it to the same treatment, he obtained 17·6 parts of Prussian-blue. Vogel found that the oil of bitter-almonds, when deprived of all the hydrocyanic acid which it contains, is still characterized by the usual smell and taste, and acts as a poison nearly as violently as when it contained the hydrocyanic acid.† It is obvious from the experiments of Robiquet, that the portion of the oil which absorbs oxygen and becomes concrete, is not poisonous, and Stange assures us that he gave the first portions of the oil, after agitating them with barytes water, both to dogs and cats without injury, though it still retained its peculiar taste and odour‡; but from his own statement it is pretty obvious that it consisted chiefly of the last portions distilled. For he assures us that a few minutes' exposure to the air was sufficient to convert it into a mass of crystals.

Oil of bitter almonds, according to Robiquet and Boutron-Charlard, absorbs chlorine gas, and deposits crystals, no doubt, of amygdalic acid. The liquid from which these crystals have fallen, has the smell of chloride of cyanogen, and mixes readily with water. When we heat this liquid, muriatic acid is disengaged, and a crystallized acid (considered as benzoic) begins to be deposited. It is obvious from this that the acid does not exist ready formed in the oil, but is produced by its absorption of oxygen, and the decomposition of water, the hydrogen of which converts the chlorine into muriatic acid.

The oil of bitter almonds combines with the alkalies.

Robiquet and Boutron-Charlard mixed the oil with caustic potash, taking care to fill a bottle, which was well stopped, with the mixture. It was kept in this state for a month, being well agitated very frequently. The oil under this treatment was completely transformed into a mass of small crystals, insoluble in the alkaline liquid, and composed of the oil and potash united. These crystals, dissolved in water forming a milky liquid, which when distilled yielded an oil almost destitute of smell.

The same chemists assure us that when oil of bitter almonds is treated with an alkali, while in contact with the atmosphere, abundance of benzoate of potash is formed.

This oil absorbs abundance of ammoniacal gas, and forms a solid compound, which may be reduced to powder, and exposed to the air without losing the ammonia which it contains.§

When this oil is treated with nitric acid, benzoic acid is formed, but in much smaller quantity than when the oil is exposed to the oxidation of the atmosphere.

When oil of bitter almonds is preserved for a long time, a peculiar

* Ann. de Chim. et de Phys. xix. 221. † Ibid. ‡ Repert. xiv. 329.
§ Karls, Poggendorf's Annalen. x. 610.

substance is formed in it which remains behind when we distil the oil along with water. This substance was examined by Bonastre. It is not volatile; it dissolves in alcohol, and crystallizes from that solution in 3- or 6-sided prisms. It is little soluble in water; melts when heated, and burns, giving out at the same time an aromatic odour.

Robiquet and Boutron-Charlard have endeavoured to prove that the oil of bitter almonds does not exist in the almonds, but is formed during the process of distillation. When the *marc* of bitter almonds is digested in ether, no volatile oil is obtained. But if we dilute this marc with water, and then digest it again in ether, the oil of bitter almonds is now obtained in solution in the ether. If we treat the marc first with ether, then with alcohol, and then with water, we obtain no trace of volatile oil.

The alcohol employed contains in solution a crystalline body, to which Robiquet and Boutron-Charlard, who discovered it, have given the name of *amygdalin*.

It has a sweet taste, leaving upon the palate an impression of bitterness, somewhat similar to the taste of bitter-almonds. It is destitute of smell. It is not volatile either by itself or when mixed with other substances likely to promote its volatility.

When heated in a glass tube it swells, emits at first the odour of caramel; while towards the end of the calcination, that of the blossoms of the *mespilus oxyacanthus*, or common hawthorn is perceptible.

It is not altered by exposure to the air. Chlorine seems to have no action on it while both are dry; but when moisture is present the amygdalin swells out, remains insoluble in water, and assumes the appearance of a resin. Alcohol is incapable of dissolving amygdalin.

When heated with a solution of caustic potash, it gives out a strong smell of ammonia, and the solution contains no trace of prussic acid. It is obvious from this that azote enters into its composition. When treated with nitric acid, some benzoic acid is formed; but the quantity obtained in this way can only be small, as nitric acid has the property of destroying benzoic acid in proportion as it is formed. It was subjected to a chemical analysis by MM. Henry, junior, and Plisson, who obtained the following result:—

Carbon	58·5616	or 39 atoms	= 29·25	or per cent.	59·09
Hydrogen	7·0857	or 28 atoms	= 3·5	— —	7·07
Azote	3·6288	or 1 atom	= 1·75	— —	3·63
Oxygen	30·7239	or 15 atoms	= 15·0	— —	30·21
	100·0000		49·5		100·00

But, from the more recent examination by Liebig, it consists of

40 atoms carbon	= 30	or per cent.	52·63
26 atoms hydrogen	= 3·25	— —	5·70
1 atom azote	= 1·75	— —	3·07
22 atoms oxygen	= 22	— —	38·60
	57		100

Oil of bitter almonds is prepared in France in great quantities for perfuming soap. Bonastre informs us that a perfumer in Paris prepares every year three hundred weight of it.

Oil of bitter almonds, as analyzed by Liebig, is composed of

14 atoms carbon	= 10·5	or per cent.		79·25
6 atoms hydrogen	= 0·75	—	—	5·66
2 atoms oxygen	= 2	—	—	15·09
	13·25			100

SECTION IV.—OF OIL OF BERGAMOTE.

It has a smell analogous to that of oranges, and is obtained from the ripe fruit of the *citrus bergamium*. It is limpid, yellowish, and fluid, has a specific gravity of 0·888. It becomes solid a little below 32°. It is much used as a perfume; but has not hitherto been subjected to a chemical examination.

SECTION V.—OF OIL OF ROSES.

This oil, called *otto* or *ottar of roses*, is obtained by distilling the petals of the *rosa centifolia* along with water. The roses in this country, and even in France, yield so little oil that it hardly pays the expense of the process. Those in Egypt are probably richer in oil, as it is from that quarter chiefly, and from India, that otto of roses comes.

Oil of roses is nearly colourless, and has the odour of roses, of course too much concentrated to be agreeable; but constituting a delicious perfume. The specific gravity of Persian oil of roses is according to Chardin 0·872, and that of French oil 0·867. When cooled below 80° it congeals into a substance like butter. This melts at 84° into a limpid oil. At the temperature of 57°, 1000 parts of alcohol (of 0·806) dissolve only $7\frac{1}{2}$, and at 72°, 33 parts of this oil. It is composed of two oils, one liquid and the other solid, the latter of which is destitute of smell. It is obtained by freezing the oil, and compressing it while solid between folds of blotting paper. It constitutes crystalline plates, which melt at about 95°, and on cooling congeal into large colourless transparent crystals. It is very little soluble in alcohol.

Blanchett has analyzed this oil and obtained

Carbon	74·07 or 23 atoms	= 17·25	or per cent.		74·59
Hydrogen	12·13 or 23 atoms	= 2·875	—	—	12·43
Oxygen	13·80 or 3 atoms	= 3·000	—	—	12·98
	100·00*	23·125			100

Blanchet also analyzed the pure crystallized stearin from oil of roses. It becomes solid when cooled down to 93°. It boils between 536° and 572°. It then smokes like boiling fixed oil, but undergoes no alteration. Its constituents were found to be

* Ann. der Pharmacie, vii. 154.

Carbon	81·18
Hydrogen	14·40
	95·58*

Saussure who also analyzed this stearin obtained

Carbon	86·743
Hydrogen	14·889
	101·632

If we suppose it to be a compound of 1 atom carbon + 1 atom hydrogen, its constituents would be

1 atom carbon	0·75	or per cent.	85·72
1 atom hydrogen	0·125	— —	14·28
	0·875		100·00

Numbers which approach pretty nearly to the result obtained by Saussure. There is probably a typographical error in the numbers given by Blanchet. He himself states the composition

Carbon	85·86
Hydrogen	14·46
	100·32

But his analysis will not admit of these numbers.

SECTION VI.—OF OIL OF JONQUILLE.

Robiquet has shown that the smell of the petals of the *narcissus jonquilla*, is owing to the presence of a volatile oil, which cannot be extracted in the usual way; but is separated when the flowers are digested in ether, and that liquid distilled off. It has the fragrance of the Jonquille; but is very easily altered in its nature.†

SECTION VII.—OF OIL OF PEPPERMINT.

This is one of the few volatile oils that is prepared in considerable quantity in this country. It is extracted from the leaves of the *mentha piperita* or common *peppermint*. It has a yellow colour, an aromatic and cooling taste, and the well known odour of peppermint. Its specific gravity is 0·92. The American oil yields crystals when cooled down, which Dumas has shown to differ from camphor, merely by containing two additional atoms of hydrogen. European oil yields no camphor. Giese assures us, that the only oil of peppermint which yields camphor, is that prepared from the dried plant gathered when in flower.

The aqueous solution of this oil, under the name of peppermint water, is occasionally used in medicine.

This oil was analyzed by MM. Blanchet and Sell, who found it composed of

* Ann. der Pharmacie, vii. 156. † Jour. de Pharmacie, xxi. 335.

Carbon	78·50 or 12 atoms	= 9	or per cent.	80
Hydrogen	11·01 or 10 atoms	= 1·25	— —	11·1
Oxygen	10·49 or 1 atom	= 1	— —	8·9
	100·00	11·25		100·0

The stearin of the oil was composed of

10 atoms carbon	= 7·5	or per cent.	76·93
10 atoms hydrogen	= 1·25	— —	12·82
1 atom oxygen	= 1	— —	10·25
	9·75*		100·00

It was obtained from American peppermint oil by cooling. It crystallized in needles, melted at 80°½, and boiled at 406°½. By boiling it became yellow, and congealed again when cooled to 75°. It may be distilled over unaltered. It is not deposited in crystals from a hot alcoholic solution; but it is from a mixture of alcohol and ether.

Oil of peppermint dissolves iodine slowly, and without elevation of temperature.†

SECTION VIII.—OF OIL OF LAVENDER.

This well known oil is extracted from the *lavandula spica*, a plant common enough in our gardens. It has a yellow colour, is very fluid, has a hot taste, and the smell of lavender. Its specific gravity varies from 0·877 to 0·905. The purest being the lightest. It is soluble in all proportions in alcohol of 0·83, but alcohol of the specific gravity 0·887 dissolves only 42 per cent. of its weight of it. When oil of lavender is agitated with concentrated acetic acid, the mixture separates into two portions, the first consisting of a chemical compound of the acid and the oil, the other of a solution of the oil in the acid. This last solution resembles water, and the acid in it is more dilute; because the first compound consists of the pure acid united to the oil. The alcoholic solution of this oil under the name of *lavender water*, is much employed as a perfume.

Saussure found that this oil left in contact with oxygen gas, for 4½ months over mercury, absorbed 119 times its volume of that gas. The residual gas amounted to 0·372 or somewhat more than a third of the oxygen gas absorbed. It consisted of

Carbonic acid	82·6
Oxygen	51
Azotic	24·5
Hydrogen	6·9
	165·0‡

SECTION IX.—OF OIL OF ROSEMARY.

This oil is extracted from the *rosmarinus officinalis*, or common *rosemary*, and was formerly distinguished in pharmacy by the name

* Annalen der Pharm. vi. 292. † Hashoff, Jour. de Pharmacie, xvii. 112.
‡ Ann. de Chim. et de Phys. xlix. 232.

of *oleum anthos*. It is limpid like water, and except in its smell, which is that of rosemary, it has a good deal of resemblance to oil of turpentine. Its specific gravity is 0·934, but by rectification Saussure obtained it as light as 0·8886. It boils at 329°. It is soluble in all proportions in alcohol of 0·83 ; but it requires 40 times its weight of alcohol to dissolve it. When kept in imperfectly-stopped phials, it gradually deposits crystals, which have been considered as camphor ; but how far they possess the properties and constitution of camphor, has not been determined by experiment.

This oil is sometimes adulterated with oil of turpentine. To discover the fraud, we have have only to mix it with its own bulk of alcohol, which will dissolve the oil of rosemary, and set the oil of turpentine at liberty.

SECTION X.—OF OIL OF ANISE.

It is extracted from the seeds of the *pimpinella anisum*. It is colourless, or slightly tinged yellow, and has the odour and taste of anise seeds. It becomes gradually solid when kept at the temperature of 50°. The camphor which it deposits will be described in a subsequent section of this chapter. Its specific gravity at 78°, was found by Saussure to be, 0·9857. It is soluble in all proportions in alcohol of 0·806, but alcohol of 0·84 dissolves only 0·42 of its weight of it.

Oil of anise analyzed by MM. Blanchet and Sell, was found composed of

Carbon	80·24
Hydrogen	8·55
Oxygen	11·21
	100·00

And the stearin from the same oil of

Carbon	80·71
Hydrogen	8·12
Oxygen	11·17
	100·00*

This gives us

10 atoms carbon	= 7·5	or per cent.	81·08
6 atoms hydrogen	= 0·75	— —	8·11
1 atom oxygen	= 1·0	— —	10·81
	9·25		100·00

The stearin was obtained by cooling down the oil to 32°, and then subjecting the solid matter to pressure, between folds of blotting paper. It was then dissolved in hot alcohol of 0·818, and crystallized. The crystals were freed from alcohol by fusion. This stearin was heavier than water. It melted when heated to 61°, and boiled at 428°. Not so soluble in alcohol as the elain of the same oil.

* Ann. der Pharm. vi. 287.

SECTION X.—OF OIL OF CAJEPUT.

This oil is prepared in the East Indies, by distilling along with water the dry leaves of the *melaleuca leucadendron*. It is said to be chiefly prepared at Banda. It has been used in India from time immemorial as a medicine, and was imported into Europe by the Dutch, and employed extensively in Germany before the plant from which it is obtained was known. This was first discovered by Linnæus in 1772.

Cajeput oil has a green colour. It is very fluid, and has a specific gravity, varying from 0·914 to 0·9274. Its taste is hot, and its smell strong and rather disagreeable. It is entirely soluble in alcohol. According to Leverköhn it consists of two oils which may be separated by distillation. Seven-eighths of the oil employed comes over colourless, and has a specific gravity of 0·897; then a green oil distils over more slowly, having a specific gravity of 0·920 and having a weaker odour, but a more acrid taste.

According to Blanchet, it boils at 343°½. When heated to 248°, its green colour disappears, and it comes over colourless. What comes over first has a specific gravity of 0·9196, and boils at 343°½. Potassium is converted by it into potash. It dissolves iodine without effervescence. Sulphuric acid changes its colour to yellow. Nitric acid does not alter it.

The constituents of this oil are (as determined by Blanchet*),

10 atoms carbon	= 7·5	or per cent.	77·92
9 atoms hydrogen	= 1·125	— —	11·69
1 atom oxygen	= 1·0	— —	10·39
	9·625		100·00

So that it differs from oil of turpentine, and of juniper, by containing an additional atom of water.

It is much used as a medicine, both externally and internally in India. Externally, it seems to act as a stimulant, and is found useful in many painful chronic diseases. Internally, when taken in from 2 to 12 drops, it acts also as a stimulant.

SECTION XII.—OF OIL OF MINT.

This oil which is rarely met with, is prepared by distilling the leaves of the *mentha crispa*, along with water. It is at first pale yellow, but by keeping, deepens into yellowish-red. Its smell and taste is similar to those of mint. Its specific gravity as determined by Dr Lewis is 0·975. When cooled down sufficiently, it becomes solid.

SECTION XIII.—OF OIL OF FENNEL.

This oil is obtained from *anethum fœniculum*. It is colourless, or has a slight shade of yellow. Its taste and smell are similar to those of the plant, from which it is extracted. Its specific gravity, as determined by Dr Lewis, is 0·997. When cooled below 50°, it

* Annalen der Pharmacie, vii. 162.

crystallizes. Two kinds of crystals are formed, the one kind in large plates is heavier than water, and much less volatile than the second, which is lighter than water, and passes over first when both are distilled together.

This oil was analyzed by Blanchet and Sell, and found composed of

Carbon . .	76·14 or $6\frac{1}{2}$ atoms
Hydrogen . .	8·49 or 4 atoms
Oxygen . .	15·47 or 1 atom
	100·00

The stearin from this oil was composed of

Carbon	79·89 or 10 atoms	= 7·5	or per cent.	81·08
Hydrogen	8·17 or 6 atoms	= 0·75	— —	8·11
Oxygen	11·94 or 1 atom	= 1·0	— —	10·81
	100·00*	9·25		100

Or the same as the stearin from anise oil. The characters of the two also corresponded, showing their identity.

SECTION XIV.—OF OIL OF DILL.

This oil is obtained from the seeds of the *anethum graveolens*. It has a light yellow colour. Its taste is sweetish and hot; its smell is very penetrating. It is soluble in 1440 times its weight of water according to Teitzmann; but dissolves readily in alcohol and water. Tietzmann says its specific gravity is 0·881; while Dr Lewis makes it as high as 0·994.

SECTION XV.—OF OIL OF CHAMOMILE.

This oil is extracted from the flowers of the *matricaria chamomilla*, or feverfew. Its colour is deep blue. It is thick and almost opaque. Its smell is similar to that of the plant from which it is obtained, and its taste aromatic. When left exposed to the air, it becomes brown and unctuous. Nitric acid dissolves it, assuming a brown colour, and water throws down from the solution a resin having the smell of musk. Sasse affirms, that if it be mixed with sulphuric acid and then with water, it burns with an explosion.

The *anthemis nobilis*, *arnica montana* and *archillea millefolium* yield also blue-coloured oils. But it has not been ascertained how far they agree with the oil of chamomile in their characters.

SECTION XVI.—OF OIL OF NUTMEGS.

There are two oils obtainable from the nutmeg, which is the fruit of the *myristica moschata;* namely a *fixed oil*, which is extracted by expression, and a volatile oil obtained by distillation with water. This last is a colourless or slightly yellow-coloured oil. Its specific gravity varies from 0·920 to 0·948. When kept it deposits a solid crystallized matter, which has been considered as camphor, but which sinks in water.† It dissolves readily in alcohol and ether,

* Ann. der Pharmacie, vi. 289. † John has given it the name of *myristicin*.

and crystallizes in prisms. Fuming nitric acid sets it on fire. With sulphuric acid it becomes reddish-brown, and deposits a resinous substance.

SECTION XVII.—OF OIL OF TANSEY.

This oil is extracted from the leaves and flowers of the *tanacetum vulgare*, or *common tansey*. It is usually yellow, but is said sometimes to have a *green* colour, when the plant has vegetated upon a fertile soil. It has the peculiar flavour of tansey, and on the continent is used in medicine.

SECTION XVIII.—OF OIL OF ASARUM.

This oil was obtained from the *asarum Europeum*, by Dr Graeger. He sent an alcoholic solution of it to MM. Blanchet and Sell, who separated it from the spirits, and ascertained its characters and composition.*

The oil has a yellow colour, has a glutinous consistence, is lighter than water, has a sharp burning taste, and the smell of valerian. It is but little soluble in water, but more soluble in alcohol, ether, fixed and volatile oils. Its constituents were

Carbon . .	76·36 or 7 atoms
Hydrogen . .	9·10 or 5 atoms
Oxygen . .	14·54 or 1 atom
	100·00

But no conclusion can be drawn from this analysis, because the oil contained in solution a quantity of asarin, or asarum camphor.

SECTION XIX.—OF OIL OF CARAWAYS.

This oil is extracted from the seeds of the *carum carvi*, has a pale yellow colour, and the odour and taste of *oil of cummin*, extracted from the *cuminum cyminum*. How far these two oils agree with each other has not been ascertained. The latter is said by Dr Lewis to be specifically heavier than the former. But in colour, fluidity, taste and smell, they agree.

SECTION XX.—OF OIL OF PIMENTO.

This oil is extracted from the covering of the fruit of the *myrtus pimenta*. It is yellowish, or almost colourless, has a smell analogous to that of cloves, an acrid taste, and a specific gravity above that of water. According to Bonastre, it combines with bases in the same way as oil of cloves; but these compounds have not yet been examined.

SECTION XXI.—OF OIL OF PARSLEY.

It is obtained from the *apium petroselinum*. Colour light yellow, has a strong odour of parsley. When agitated with water it is

* Annalen der Pharmacie, vi. 296.

divided into a fluid portion, which swims on the surface of the water, and a solid portion, which falls to the bottom. This last portion may be crystallized, and has been considered as camphor. It melts at 86°.

The *camphor* from this oil was analyzed by MM. Blanchet and Sell. They obtained

Carbon	65·53 or 6 atoms	= 4·5	or per cent.	65·46
Hydrogen	6·38 or 3 atoms	= 0·375	— —	5·45
Oxygen	28·09 or 2 atoms	= 2·0	— —	29·09
	100·00*	6·875		100·00

Thus it differs greatly from common camphor, which is a compound of

10 atoms carbon	= 7·5
8 atoms hydrogen	= 1
1 atom oxygen	= 1
	9·5

It contains much more oxygen, and less hydrogen. Blanchet and Sell consider it as a hydrate of oil of parsley.

The fresh parsley oil was changed into the camphor, by agitation for some days in water. It was pressed between folds of blotting paper, and dissolved in alcohol. It crystallized in 6-sided prisms, melted at 86°, and congealed again at 70°. It boiled at 572°, and became brown, but could not be sublimed.

SECTION XXII.—OF OIL OF SASSAFRAS.

This oil is obtained from the root of the *laurus sassafras*. When new it is colourless, but by keeping, becomes yellow or even red. It has the smell of sassafras, and a hot taste. Its specific gravity is 1·094. When agitated with water it separates, like oil of parsley, into 2 portions, a fluid oil which swims on the surface of the liquid, and a heavier oil which, though still fluid, falls to the bottom. It has been supposed that the lighter oil is nothing else than oil of turpentine, with which the oil of sassafras has been adulterated. But this is contradicted by the experiments of Bonastre.† By keeping, this oil deposits crystals, which have the smell and taste of the oil. The specific gravity of these crystals, at 43°, is 1·245. They melt at 54°½, and the specific gravity is then said to be only 1·110. These crystals are scarcely soluble in water; but they dissolve readily in alcohol, and the solution is not precipitated by water. They are not soluble in muriatic or acetic acid, or caustic potash, even when assisted by heat. When treated with boiling nitric acid, they yield oxalic acid.‡

When subjected to a current of chlorine gas, it becomes thick. opaque, and white. It scarcely combines with the caustic alkalies. When long exposed to the contact of ammonia, it becomes muddy

* Poggendorf's Annalen, xxix. 134. † Jour. de Pharmacie, xiv. 647.
‡ Bonastre, Jour. de Pharmacie, xiv. 579.

and thick, but no crystals are formed. When this muddy oil is kept for some time in a phial with a ground stopper, $\frac{2}{3}$ds of it recover their original fluidity.

In commerce this oil is found adulterated by a mixture of oil of lavender. The adulterated oil consists usually of 2 parts oil of sassafras, and 1 part oil of lavender. It has a yellow colour, and when poured into water, the greatest part swims on the surface, while a certain portion sinks to the bottom. Both portions are reddened by nitric acid, a property which characterizes oil of sassafras.

Sometimes it is adulterated with oil of turpentine. If we mix such an adulterated oil with water, and distil cautiously, the oil of turpentine passes over first; and then the oil of sassafras; so that the two oils may in this way be completely separated.

Sometimes oil of sassafras is mixed at once with oil of turpentine and oil of cloves. To separate these three oils, M. Bonastre put into a retort 300 parts of the mixture, 100 parts of caustic soda, and the requisite quantity of water, and distilled. The oil of turpentine was found swimming on the surface of the liquid, in the receiver, and the oil of sassafras at the bottom of that liquid. The residue in the retort being concentrated, deposited crystals, which consisted of a combination of oil of cloves and soda.*

SECTION XXIII.—OF OIL OF BASIL.

This oil is obtained from the *ocymum basilicum*. I merely mention it here, in order to notice a crystallized substance observed in it by M. Bonastre.†

The crystals were 4-sided pyramids, with very acute faces. They were very little soluble in cold water, but very soluble in boiling water, and were again deposited when the solution cooled. They were partly soluble in cold alcohol, and the solution reddened vegetable blues. Boiling alcohol dissolves them completely, and they are deposited again when the solution cools. The crystals from the aqueous solution had scarcely any taste; those from the alcoholic had the smell and taste of oil of basil. 6 parts of ether scarcely dissolved 1 part of these crystals. They were very soluble in cold nitric acid, and acetic acid. Sulphuric acid gave them a red colour. Caustic ammonia dissolved them. Water rendered the solution muddy, but no frothing was produced.

SECTION XXIV.—OF OIL OF HOPS.

This oil may be obtained either by distillation, or by means of alcohol, from the common hops, which are the blossoms of the *humilus lupilus*. It has a greenish-yellow colour, and has the peculiar odour and taste which distinguishes hops. Its specific gravity is 0·910. It is converted, by keeping, into a kind of resin. When hops are digested in alcohol, a greenish-yellow solid matter is obtained, consisting partly of oil and partly of resin. The older the

* Bonastre, Jour. de Pharmacie, xiv. 645. † Jour. de Pharmacie, xvii. 646.

hops, the greater is the quantity of resin. It is said by Payen and Chevallier to be soluble in 10,000 times its weight of water.*

SECTION XXV.—OF OIL OF WHISKY.

Whisky owes its peculiar flavour to a volatile oil which exists in the barley from which the spirits have been made. It dissolves in 6 times its weight of alcohol, and in twice its weight of ether. Its colour is white, and it becomes solid at a temperature not very low, and then has the aspect of tallow. Its flavour and taste are disagreeable. It is lighter than water, and even than common spirits. Water dissolves very little of it. When spirits, strongly impregnated with this oil, are diluted with water, the oil separates, rendering the mixture at first milky. Caustic potash dissolves it very slowly. Whisky may be deprived of this oil, which injures its natural flavour, by agitation with animal charcoal.

SECTION XXVI.—OF OIL OF BRANDY.

This oil may be obtained by distilling the fermented residue of grapes. It distils over after the brandy has passed. It is limpid and very fluid, has a strong smell, and an acrid taste. It becomes yellow when exposed to the air. It is soluble in 10,000 times its weight of water, to which it communicates its peculiar odour and flavour. It is said to combine with the caustic alkalies. When distilled over, it is partly converted into an empyreumatic oil.

SECTION XXVII.—OF OIL OF POTATOES.

It is well known that a spirit can be extracted from potatoes. From this spirit MM. Bertillon and Guietand extracted a volatile oil, which M. Pelletan found possessed of the following properties:—

A colourless limpid liquid, having a strong smell, and a hot acrid taste. It does not stain paper. Its specific gravity at 61° is 0·821. It is still fluid when cooled down to zero, but it congeals at a few degrees more cold, and assumes the appearance of concrete anise oil. It boils at 257°. It burns without smoke, but requires to be heated, in order to continue burning.

It is partly soluble in water, and very soluble in alcohol. It dissolves tallow, and mixes with the fixed and volatile oils. Sulphuric acid may be mixed with it, and assumes a crimson colour. Water separates the oil. When heat is applied, sulphurous acid is disengaged. It is insoluble in nitric acid. When the mixture is heated, nitric ether is obtained. Chlorine gives it a green colour. It mixes with acetic acid in all proportions. It dissolves potash, soda, and ammonia, but is not converted into soap. Potassium decomposes it with rapidity.†

But the oil, as examined by M. Pelletan, obviously contained

* Jour. de Pharm. viii. 214 and 533.

† Ann. de Chim. et de Phys. xxx. 221.

much alcohol. Dumas found that when purified by cautious distillation, it boils at 269°, is limpid and colourless, and has a disagreeable smell. He analyzed it, and found it composed of

Carbon	67·96
Hydrogen	13·66
Oxygen	18·38
	100*

These numbers correspond with

5 atoms carbon	= 3·75	or per cent. 68·18
6 atoms hydrogen	= 0·75	— — 13·62
1 atom oxygen	= 1·0	— — 18·20
	5·5	100·00

Dumas found the specific gravity of the vapour of this oil 3·147. Now

5 volumes carbon . .	= 2·0833
6 volumes hydrogen . .	= 0·4166
½ volume oxygen . .	= 0·5555
	3·0555

Hence we see that the vapour consists of 5 volumes carbon, 6 volumes hydrogen, and half a volume of oxygen, condensed into 1 volume.

DIVISION III.—OF ACRID AND VESICATING OILS.

The number of these oils at present known is not great. They all seem to contain sulphur as one of their constituents: whether the vesicating property be connected with this constituent, we do not know.

SECTION I.—OF OIL OF MUSTARD.

It has been shown by the experiments of Robiquet, Boutron-Charlard, Fauré,† Hesse,‡ and Henry and Garot, that the volatile oil of mustard does not exist ready formed in the seeds of the plant, but is formed by the action of water during the distillation. It may be obtained in the same way as volatile oil of almonds.

Its colour is usually brown; but M. Boutron-Charlard has succeeded in obtaining it very nearly colourless. It is, when in that state, limpid and very fluid. Its specific gravity at 68° is 1·015. It boils at 289°½. Its smell is excessively strong and penetrating.

It is very soluble in alcohol and ether, and is separated from these solutions by water. While hot it dissolves a great quantity of sulphur, which separates in crystals when the solution cools. It dis-

* Ann. de Chim. et de Phys. lvi. 314.

† Jour. de Pharmacie, xxi. 464. ‡ Annalen der Pharmacie, xiv. 41.

solves likewise a good deal of phosphorus while hot. On cooling down, the phosphorus separates in a liquid state till the oil cools down to 108° (the melting point of phosphorus), below which the phosphorus separates in crystals.

Chlorine acts upon this oil, and muriatic acid is formed. When alkalies are heated with it, there are produced at the same time sulphurets of the alkalies and sulphocyanodides.

Nitric acid and aqua regia act upon it with energy, and a great quantity of sulphuric acid is formed.*

The specific gravity of its vapour, as determined by Dumas and Pelouze, is 3·40.

An analysis of it by Henry and Garot has been given in the *Chemistry of Inorganic Bodies* (ii. 182). These gentlemen showed that it contained sulphur, carbon, hydrogen, azote, and oxygen. Since that time, the method of analyzing such substances has been greatly improved, and the oil has been obtained in a state of greater purity. This induced Dumas and Pelouze to analyze it again. They obtained the following results :—

Sulphur	20·26
Carbon	49·53
Hydrogen	5·02
Azote	13·45
Oxygen	11·74
	100·00†

These numbers have led Dumas and Pelouze to fix upon the following as the atomic constituents of this oil :—

2½	atoms sulphur .	= 5	or per cent.	20·62
16	atoms carbon .	= 12	— —	49·48
10	atoms hydrogen .	= 1·25	— —	5·16
2	atoms azote .	= 3·5	— —	14·43
2½	atoms oxygen .	= 2·5	— —	10·31
		24·25		100·00

If we suppose these volumes to be united together, and condensed into ¼th part of their bulk, we obtain for the specific gravity of the vapour of this oil, 3·39, a number which almost coincides with the specific gravity, as determined experimentally by Dumas and Pelouze.

The great quantity of oxygen and sulphur contained in this oil, together with the previous experiments of Henry and Garot, naturally led Dumas and Pelouze to examine whether it possessed acid qualities. But as those bases which contain oxygen alter its nature, they were obliged to have recourse to ammonia. They found that it was absorbed rapidly by the oil, and that a new compound was formed, which was soluble in water, and capable of being crystal-

* Dumas and Pelouze ; Ann. de Chim. et de Phys. liii. 182. † Ibid. p. 183.

lized. But it did not possess the characters of a salt, for neither acids nor bases were capable of separating the oil from it. It was rather one of the family of *amides*, which are now becoming so numerous. This new substance is easily obtained: we have only to put into a phial, furnished with a ground stopper, a quantity of the oil together with an excess of ammonia dissolved in water. In a few days the oil disappears, and we find in its place a mass of beautiful crystals. These crystals, when dissolved in water, and treated with animal charcoal, may be obtained perfectly free from colour.

They are then of a shining white, melt at 158°, have no smell, but a bitter taste.

They are more soluble in hot than in cold water. Alcohol and ether dissolve them also. The boiling alkalies disengage ammonia from this substance; but the evolution is very slow. Nitric acid destroys it, and leaves sulphuric acid. These crystals were analyzed by Dumas and Pelouze, who obtained

Sulphur	16·89
Carbon	42·65
Hydrogen	6·91
Azote	24·62
Oxygen	8·93
	100·00

These results give

$2\frac{1}{2}$ atoms sulphur	= 5	or per cent.		17·55
16 atoms carbon	= 12	—	—	42·10
16 atoms hydrogen	= 2	—	—	7·01
4 atoms azote	= 7	—	—	24·56
$2\frac{1}{2}$ atoms oxygen	= 2·5	—	—	8·78
	28·5			100·00

Now the oil is $S^{2\frac{1}{2}}\ C^{16}\ H^{10}\ Az^2\ Ox^{2\frac{1}{2}}$

The amide is $S^{2\frac{1}{2}}\ C^{16}\ H^{10}\ Az^2\ O^{2\frac{1}{2}} + Az^2\ H^6$

which is 1 atom oil, and 2 atoms of ammonia.

SECTION II.—OF OIL OF HORSE RADISH.

This oil is extracted from the *cochlearia armoracia*, or *horse radish*. It has a light-yellow colour, and has the same consistency with oil of cinnamon, and is heavier than water. It has an exceedingly strong smell of horse radish, and excites tears. It is so volatile, and the smell is so strong, that a single drop of the oil is sufficient to infect a large room. Its first impression when put into the mouth, is that of sweetness; but it speedily inflames the lips and tongue. It is slightly soluble in water, and communicates to that liquid its smell, and its property of inflaming the skin. This solution precipitates acetate of lead brown, and nitrate of silver black. Both these precipitates are sulphurets, showing that the oil contains sulphur.

Alcohol dissolves this oil readily. When long kept, it deposits bright crystalline needles, which have the smell, and the stimulating properties of the oil. These crystals melt when heated, and sublime without leaving any residue.*

It is hardly necessary to remark, that it is to this oil that horse radish owes its taste and its property of raising a blister when applied to the skin.

SECTION III.—OF SCURVY-GRASS OIL.

This oil is extracted from the *cochlearia officinalis*, or *scurvy grass*. Colour yellow, odour strong, exciting tears, taste acrid, heavier than water. Very volatile. Soluble in alcohol, along with which it may be distilled. The alcoholic solution is employed on the continent as a medicine, under the name of *spirit of cochlearia*.

SECTION IV.—OF OIL OF GARLIC.

This oil is extracted from the bulbs and stem of the *allium sativum*, or *garlic*. Colour yellow, smell that of garlic, taste acrid, heavier than water. Very volatile. When applied to the skin it occasions violent pain. When burnt it emits a smell of sulphurous acid, showing that it contains sulphur as a constituent. It is very soluble in alcohol.†

A similar oil is obtained from onions, the *allium cepa* of botanists. It is colourless, and contains also sulphur as a constituent. It was obtained and slightly examined by Fourcroy and Vauquelin.

In this Chapter the properties of the most important volatile oils have been stated. It would be an endless, and indeed impossible task to enumerate them all; but the following table contains a pretty copious list of plants which yield volatile oils. The part of the plant from which it is extracted, and the English name of the oil, are added in separate columns.‡

Plants.	Parts.	Oil of	Colour.
1. Artemisia absynthium	Leaves	Wormwood	Green
2. Acorus calamus	Root	Sweet flag	Yellow
3. Myrtus pimenta	Fruit	Jamaica pep.§	Yellow
4. Anethum graveolens	Seeds	Dill	Yellow
5. Angelica archangelica	Root	Angelica	
6. Pimpinella anisum	Seeds	Anise	White
7. Illicium anisatum	Seeds	Stellat. anise	Brown
8. Artemisia vulgaris	Leaves	Mugwort	
9. Citrus aurantium	Rind of the fruit	Bergamotte	Yellow
10. Meloleuca leucodendra	Leaves	Cajeput	Green
11. Eugenia caryophyllata	Capsules	Cloves§	Yellow

* Einhoff, Gehlen's Jour. v. 365. † Cadet. ‡ See Gren's Handbuch, ii. 204.
§ The oils marked § sink in water.

Plants.	Parts.	Oil of	Colour.
12. Carum carvi	Seeds	Caraways	Yellow
13. Amomum cardamomum	Seeds	Card. seeds.	Yellow
14. Carlina acaulis	Roots		White
15. Scandix chaerefolium	Leaves	Chervil	Sulph. yel.
16. Matricaria chamomilla	Petals	Chamomile	Blue
17. Laurus cinnamonum	Bark	Cinnamon§	Yellow
18. Citrus medica	Rind of the fruit	Lemons	Yellow
19. Cochlearia officinalis	Leaves	Scurvy grass	Yellow
20. Copaifera officinalis	Extract	Copaiba	White
21. Coriandrum sativum	Seeds	Coriand. seed	White
22. Crocus sativus	Pistils	Saffron§	Yellow
23. Piper cubeba	Seeds	Cubeb pep.	Yellow
24. Laurus culilaban	Bark	Culilaban	Brown yel.
25. Cuminum cyminum	Seeds	Cummin	Yellow
26. Inula helenium	Roots	Elecampane	White
27. Anethum fæniculum	Seeds	Fennel	White
28. Croton eleutheria	Bark	Cascarilla	Yellow
29. Maranta galanga	Roots	Galanga	Yellow
30. Hyssopus officinalis	Leaves	Hyssop	Yellow
31. Juniperus communis	Seeds	Juniper	Green
32. Lavendula spica	Flowers	Lavender	Yellow
33. Laurus nobilis	Berries	Laurel	Brownish
34. Prunus laurocerasus	Leaves	Lauroceras.§	
35. Levisticum ligusticum	Roots	Lovage	Yellow
36. Myristica moschata	Seeds*	Mace	Yellow
37. Origanum majorana	Leaves	Majorum	Yellow
38. Pistacia lentiscus	Resin	Mastich	Yellow
39. Matricaria parthenium	Plant	Motherwort	Blue
40. Melissa officinalis	Leaves	Balm	White
41. Mentha crispa	Leaves		White
42. ——— piperitis	Leaves	Peppermint	Yellow
43. Achillea millefolium	Flowers	Millefoil	Blue and green
44. Citrus aurantium	Petals	Neroli	Orange
45. Origanum creticum	Flowers	Spanish hop	Brown
46. Apium petroselinum	Roots	Parsley	Yellow
47. Pinus sylvestris et abies	Wood & resin.	Turpentine	Colourless
48. Piper nigrum	Seeds	Pepper	Yellow
49. Rosmarinus officinalis	Plant	Rosemary	Colourless
50. Mentha pulegium	Flowers	Pennyroyal	Yellow
51. Genista canariensis	Root	Rhodium	Yellow
52. Rosa centifolia	Petals	Roses	Colourless
53. Ruta graveolens	Leaves	Rue	Yellow

§ The oils marked § sink in water. * They yield also a fixed oil.

Plants.	Parts.	Oil of	Colour.
54. Juniperus sabina	Leaves	Savine	Yellow
55. Salvia officinalis	Leaves	Sage	Green
56. Santalum album	Wood	Santalum§	Yellow
57. Laurus sassafras	Root	Sassafras	Yellow
58. Satureia hortensis	Leaves	Satureia	Yellow
59. Thymus serpillum	Leaves & flower	Thyme	Yellow
60. Valeriana officinalis	Root	Valerian	Green
61. Kæmpferia rotunda	Root	Zedoary	Greenish blue
62. Amomum Zinziber	Root	Ginger	Yellow
63. Andropogon schænanthum		Sira	Brown

Several of the gum resins, as *myrrh* and *galbanum*, yield likewise an essential oil, and likewise the balsams, as *benzoin*, &c.

DIVISION IV.—OF CAMPHORS.

The term *camphor* has been applied by apothecaries to various solid bodies which occasionally appear in volatile oils. They are distinguished by their great volatility, by a strong and peculiar smell, by the property of melting when heated, and burning brilliantly when held to a lighted candle. By far the most important of these bodies is the well known substance constituting common camphor.

SECTION I.—OF COMMON CAMPHOR.

Camphor was unknown to the Greeks and Romans; but appears to have been introduced into medicine by the Arabian physicians, and to have been distinguished by the name of *kamphur*. Hence the Greek and Latin word *camphora*, and our English word *camphor*. Ætius is the first person who notices it. He was physician in the Court of Constantinople, about the middle of the 6th century, and his writings were much admired and studied during the 15th and 16th centuries. Paracelsus mentions it repeatedly in his writings, and from the way in which he speaks of it, one would suppose that it must have been in common use in his time.* Yet I cannot find any allusion to it in the *Praxis Chymeatrica* of Joannes Hartmannus, printed at Geneva in 1647. There is an account of its medical uses in the *Pharmacopée Royale* of Charas, printed at Paris in 1676 (p. 704). Van Helmont notices its solubility in nitric acid, and says that it may be thrown down unaltered by water.† The first person who examined its properties in detail was Neumann, in his

§ The oils marked § sink in water.

* Thus, in his treatise *De Caducis*, he classes it with *mumia*, *spodium*, and other common medicines of the time. Opera Paracelsi, i. 673 (Geneva edition, of 1658).

† De lithiasi, p. 24.

well known dissertation on it, published in 1725.* He gives an account of its chemical characters, and shows that it differs from oils, resins, and gums, and that it is entitled to rank as a peculiar vegetable principle. He mentions in this paper, that he had obtained from oil of thyme a crystallized substance, possessed of all the characters of camphor, except the colour.

It comes to Europe chiefly from Japan. It is obtained from the *laurus camphora*, a tree common in the East, by distilling the wood along with water in large iron pots, on which are fitted earthen heads stuffed with straw. The camphor sublimes, and concretes upon the straw in the form of a grey powder.† It is afterwards refined in Europe by a second sublimation. The vessels are of glass, and somewhat of the shape of a turnip, with a small mouth above loosely covered with paper. According to Ferber, about $\frac{1}{4}$th of pounded chalk is mixed with the crude camphor‡; but others assure us that there is no addition whatever employed. According to Lewis, nothing more is necessary than a proper regulation of the fire§; and Professor Robison, who witnessed the process as well as Neumann, informs us, that the camphor in the subliming vessel is in a liquid state, which it could scarcely be if quick-lime were employed, at least in any considerable quantity.‖

The quantity of quick-lime used is said, by Berzelius, to amount to $\frac{1}{12}$th of the camphor. It is necessary to keep the upper part of the subliming vessel only a very little below the temperature at which camphor melts. This causes the camphor to concrete into a cake.

Camphor is a white brittle substance, having a peculiar aromatic odour, and a strong hot acrid taste. Its specific gravity is 0·9887.¶

It melts at the temperature of 288°, and boils when heated to 400°, according to my experiments.**

It is not altered by atmospheric air; but it is so volatile, that if it be exposed during warm weather in an open vessel, it evaporates completely.

When slowly sublimed, or when a hot alcoholic saturated solution is allowed to cool, it crystallizes in octahedrons, or in six-sided plates and pyramids.††

It is insoluble in water; but it communicates to that liquid a certain portion of its peculiar odour.‡‡

* Phil. Trans. vol. xxxiii. p. 321.

† Neumann's Chem. p. 319.

‡ Gren's Handbuch, ii. 219.

§ Neumann, ibid.

‖ Black's Lectures, ii. 351. See Gay-Lussac, Ann. de Chim. et de Phys. viii. 75.

¶ According to Brisson. Dr Shaw states it at 0·996 (Shaw's Boyle, ii. 346); and this has been copied into most of the recent chemical books. Probably it varies in its density considerably.

** Gay-Lussac says, that it melts at 349°, and boils at 399° (Ann. de Chim. et de Phys. viii. 78). This statement does not agree with my experience on the subject.

†† Romieu.

‡‡ From the experiments of Cadet, it appears that a French pint of water dissolves about 16 grains of camphor, and that the camphor may be precipitated by pure potash. Ann. de Chim. lxii. 132.

It dissolves readily in alcohol, and is precipitated again by water. According to Neumann, well rectified alcohol dissolves $\frac{3}{4}$ths of its weight of camphor. By distillation the alcohol passes over first and leaves the camphor. This property affords an easy method of purifying camphor. Dissolve the camphor in alcohol, distil off the spirit, and melt the camphor into a cake in a glass vessel.* If the alcoholic solution of camphor be diluted with water as much as possible, without causing the camphor to precipitate, small crystals of camphor resembling feathers gradually form.†

Camphor is soluble also in oils, both fixed and volatile. If the solution be made by means of heat, as it cools part of the camphor precipitates, and assumes the form of plumose or feather-like crystals.‡

It dissolves in bisulphuret of carbon, and the solution may be mixed with alcohol but not with water.§

Camphor is not acted on by alkalies, either pure or in the state of carbonates. Pure alkalies indeed seem to dissolve a little camphor; but the quantity is too small to be perceptible by any other quality than its odour.‖ Neither is it acted on by any of the neutral salts which have hitherto been tried.

Acids dissolve camphor without effervescence, and in general it may be precipitated unaltered from the recent solution.

To Mr Hatchett we are indebted for an accurate investigation of the action of sulphuric acid on camphor. Upon 100 grains of powdered camphor he poured 1 ounce of sulphuric acid. The camphor immediately became yellow, and gradually dissolved while the acid changed, first to brownish-red, and afterwards to brown. In about an hour the liquid became blackish-brown, and began to emit abundance of sulphurous acid gas. In four hours the whole appeared like a thick black liquid, and no other smell except that of sulphurous acid could be distinguished in it. As, during two days, no farther alteration took place, the alembic containing the solution was put upon a sand-bath moderately warm, by which means an additional quantity of sulphurous acid gas was driven off. After two days the liquid was slowly mixed with 6 ounces of water. It became reddish-brown, a considerable coagulum of the same colour subsided, the sulphurous acid smell became imperceptible, and was succeeded by a smell similar to that of a mixture of the oils of lavender and peppermint. The whole was now slowly distilled. The water which came over had the same smell as the original liquid, and there floated over it a little yellowish oil. A blackish-brown mass remained behind, not acted on by water; but alcohol extracted a resinous substance, and acquired a blackish-brown colour. What remained was charcoal. Thus, by the action of sulphuric acid, the camphor was decomposed and con-

* This process, proposed by Lewis (Neumann's Chem, p. 320), is surely preferable to that of Trommsdorf, who precipitates the camphor by water from the alcohol, and then melts it into a cake. See Gren's Handbuch, ii. 220.

† Romieu, Mem. Par. 1756, p 41. ‡ Romieu, ibid.

§ Lampadius. ‖ Bouillon la Grange, Ann. de Chim. xxiii. 154.

verted into oil, blackish-brown resin, and charcoal. The proportion of each was as follows:—

Yellow oil	3 grains
Charcoal	53
Resinous substance . .	49
	105

Making an increase of 5 grains, either from water which was retained by the resinous-like substance, or from oxygen with which it had combined.

This resinous-like substance, thus obtained, was in reality a species of artificial tannin. It was very brittle, had the odour of caromel, and an astringent taste. It dissolved in cold water, and the solution precipitated iron, lead, tin, and lime, dark brown. It precipitated gold in the metallic state, threw down isinglass in the state of a blackish insoluble substance, and had the property of converting skin into leather. A small quantity of nitric acid converted it into the artificial tannin obtained from charcoal by nitric acid.*

From the farther researches of Chevreul on this subject, it appears that when sulphuric acid is distilled off camphor, there is formed, 1. A volatile oil which has the odour of camphor: 2. A charry matter, which is a combination of sulphuric acid and a hydroguretted charcoal: 3. An astringent substance, which is likewise a compound of sulphuric acid, and a charcoal still more hydroguretted than the preceding. The charry residuum is not sensibly soluble in water. When distilled it gives sulphurous acid, carbonic acid, and leaves a residue, which is a compound of carbon and sulphur.†

Nitric acid dissolves camphor readily, and in great abundance. The solution separates into two portions; that which contains the camphor, and most of the acid, floats upon the top of the other in the form of a very pale yellow oil. This solution is known by the name of *oil of camphor*. Water and several metals precipitate the camphor unaltered.‡ Alcohol combines with the oil of camphor. When this solution of camphor in nitric acid is long kept, a portion of the camphor separates in crystals, and swims on the surface, and a small portion is converted into camphoric acid.§

Muriatic, sulphurous, and fluoric acids, in the state of gas, dissolve camphor. When water is added, the camphor appears, unaltered, in flakes which swim on the surface of the water.‖ It is dissolved also by water impregnated with carbonic acid gas,¶ by acetic acid,** and probably by all acids.

It absorbs, according to the experiments of Saussure, 144 times

* Hatchett's additional Experiments on Artificial Tannin, Phil. Trans. 1805.

† Ann. de Chim. lxxiii. 167. ‡ Neumann's Chemistry, p. 321.

§ Planche found these changes in a phial of oil of camphor, which had been kept unopened for 14 years. Ann. de Chim. xliii. 346.

‖ Fourcroy. ¶ Jour. de Phys. lii. 67.

** Phil. Mag. xv. 156. Aromatic vinegar consists chiefly of this compound.

its volume of muriatic acid gas, and assumes the form of a colourless liquid-like water, which speedily congeals in the air, the watery vapour which is absorbed by the acid separating it from the camphor.

When heat is applied to camphor it is volatilized. It catches fire very readily, and emits a great deal of flame as it burns, but it leaves no residuum. It is so inflammable that it continues to burn even on the surface of water. When camphor is set on fire in a large glass globe filled with oxygen gas, and containing a little water, it burns with a very bright flame, and produces a great deal of heat. The inner surface of the glass is soon covered with a black powder, which has all the properties of charcoal; a quantity of carbonic acid gas is evolved; the water in the globe acquires a strong smell, and is impregnated with carbonic acid and camphoric acid.*

If 2 parts of alumina and 1 of camphor be formed into a paste with water, and distilled in a glass retort, there comes over into the receiver (which should contain a little water, and communicate with a pneumatic apparatus) a volatile oil of a golden-yellow colour, a little camphoric acid, which dissolves in the water, and a quantity of carbonic acid gas and carburetted hydrogen gas, which may be collected by means of a pneumatic apparatus. There remains in the retort a substance of a deep black colour, composed of alumina and charcoal. By this process, from 122·284 parts of camphor, M. Bouillon la Grange, to whom we are indebted for the whole of the analysis of camphor, obtained 45·856 parts of volatile oil, and 30·571 parts of charcoal. The proportion of the other products was not ascertained.†

Bouillon la Grange showed that the constituents of camphor are carbon and hydrogen. I made an ultimate analysis of it by means of oxide of copper, from which it appeared that oxygen also enters into it as a constituent. It was afterwards analyzed by Saussure and Göbel.‡ But a more accurate analysis was made by Liebig, in 1831.§ It is obvious, from his own statements, that the result is not perfectly exact; but the volatility of the camphor renders the experiment very difficult of performance. He obtained

Carbon	81·763	or 12 atoms	= 9	or per cent.	80·89
Hydrogen	9·702	or 9 atoms	= 1·125	— —	10·12
Oxygen	8·535	or 1 atom	= 1	— —	8·99
	100·000		11·125		100

But camphor has been still more lately analyzed by Dumas.‖ He obtained

Carbon	78·02	or 10 atoms	= 7·5	or per cent.	78·94
Hydrogen	10·39	or 8 atoms	= 1	— —	10·53
Oyxgen	11·59	or 1 atom	= 1	— —	10·53
	100·00		9·5		100·00

* Bouillon la Grange, Ann. de Chim. xxiii. 168. † Ibid. 157.
‡ Schweigger's Jour. xl. 356.
§ Ann. de Chim. et de Phys. xlvii. 95. ‖ Ibid. l. 227.

Dumas found the specific gravity of the vapour of camphor 5·468. Now,

10 volumes carbon . .	= 4·1666
8 volumes hydrogen .	= 0·5555
½ volume oxygen . .	= 0·5555
	5·2777

So that camphor vapour consists of 10 volumes carbon, 8 volumes hydrogen, and ½ volume oxygen condensed into 1 volume.

The analysis of camphor by Blanchet and Sell in 1833, agrees very nearly with that of Dumas. They obtained

Carbon	77·96
Hydrogen	10·61
Oxygen	11·43
	100·00*

Camphrone. This substance was discovered by M. Fremy, in 1835.† He obtained it in the following way:—

A quantity of lime was put into a porcelain tube, which was heated red hot. When the requisite temperature was obtained, fragments of camphor were introduced, which made its way through the lime, and there was obtained a liquid, to which Fremy has given the name of camphrone.

It is a liquid slightly coloured, has a strong and characteristic odour, quite different from that of camphor. By a single distillation it gives a light oil, soluble in alcohol and ether, but insoluble in water. It boils at 167°.

It was analyzed by M. Fremy, who obtained

Carbon	85·03 or 24 atoms	= 18	or per cent.		85·21
Hydrogen	10·21 or 17 atoms	= 2·125	—	—	10·06
Oxygen	4·76 or 1 atom	= 1	—	—	4·73
	100·00	21·125			100·00

Now, camphor is C^{12} H^{9} O^{1}. Consequently

2 atoms of camphor .	C^{24} H^{18} O^{2}
1 atom of camphrone .	C^{24} H^{17} O

It is, therefore, 2 atoms of camphor, deprived of 1 atom of water.

M. Fremy found the complete combustion of camphrone attended with considerable difficulty. It sometimes contains camphor. To be certain of its purity we take care that its boiling point is 167°; or that, when evaporated upon a slip of glass it does not leave any trace of camphor.

Dumas subjected the camphor from oil of lavender to a chemical analysis, and found its composition exactly the same as that of common camphor.

He distinguishes by the name of *camphogene*, what he considers as the basis of camphor. It is a volatile oil composed of 10 atoms

* Ann. der Pharmacie, vi. 304. † Ann. de Chim. et de Phys. lix. 16.

carbon and 8 atoms hydrogen. It may be extracted pure from the artificial camphor formed, by uniting oil of turpentine and muriatic acid. Camphor consists of an integrant particle of camphogene united to an atom of oxygen.

Common camphor, obtained by distillation from the *laurus camphora*, is the substance which has been described in the preceding part of this Section. In Borneo and Sumatra camphor is procured from the *laurus sumatrensis;* but as none of this camphor is brought to Europe, we do not know how far it agrees with common camphor in its properties. The *laurus cinnamonum* likewise yields camphor.

SECTION II.—CAMPHOR FROM OIL OF PEPPERMINT.

American oil of peppermint has the property of congealing when cooled down within a few degrees of 32°. Prismatic crystals make their appearance in it at that temperature, which are easily isolated. They bear a very considerable resemblance to camphor. It is curious that European oil of peppermint does not yield these crystals even when cooled down below 32°. At the time that the cholera was prevalent in France, great quantities of this oil were imported from America.

The crystals are white, melt at 77°, and may be volatilized without decomposition. They are little soluble in water, but are soluble in alcohol, ether, and volatile oils. They have the taste and the smell of oil of peppermint. Being subjected to analysis by Dumas, he obtained

Carbon	76·50 or 10 atoms	=	7·5	or per cent.	76·92
Hydrogen	13·11 or 10 atoms	=	1·25	— —	12·82
Oxygen	10·39 or 1 atom	=	1·0	— —	10·26
	100		9·75		100

Thus it differs from common camphor, by containing 2 more atoms of hydrogen.*

SECTION III.—CAMPHOR FROM OIL OF ANISE.

It has been long known that when oil of anise is exposed to cold it divides into two substances, the one liquid, and the other solid. Dumas separated the solid portion, which has been considered as camphor, and subjected it to analysis. He obtained

Carbon	80·18 or 10 atoms	=	7·5	or per cent.	81·08
Hydrogen	8·28 or 6 atoms	=	0·75	— —	8·11
Oxygen	11·54 or 1 atom	=	1·0	— —	10·81
	100·00		9·25		100·00

Thus it contains 2 atoms of hydrogen less than common camphor.

It is probable that oil of peppermint and oil of anise, while liquid, consist, the former of C^{10} H^{10}, the latter of C^{10} H^{6}, and that they become solid by uniting with an atom of oxygen.

* Ann. de Chim. et de Phys. lix. 233.

SECTION IV.—OF CAMPHOR FROM OIL OF CUBEBS.

Vauquelin, in his analysis of the berries of *piper cubeba*,* noticed a volatile oil, which he extracted from them, and which was nearly solid. Teschemacher obtained crystals from this oil. It was examined in 1832 by M. Müller,† who, from 2 lbs. of cubebs, obtained about 2 ounces of a thick muddy oil, having a crystalline deposit. The specific gravity of the oil was found by Winkler 0·936. This deposit was dissolved in alcohol, and being left to spontaneous evaporation, deposited crystals in four-sided rhomboidal prisms. They were transparent, had an acrid and aromatic taste, and a strong smell of cubebs. When heated they melted, and when the temperature was farther raised, the liquid began to boil, and was volatilized in the form of a thick white smoke, which condensed again into crystals. They dissolve readily in alcohol, and the solution is neutral. Ether dissolves them as readily as alcohol, but they are insoluble in water. They dissolve also in oil of turpentine, and in the fixed oils, especially when assisted by heat. Acetic acid does not dissolve them even when assisted by heat. When they are agitated with very concentrated acetic acid, we obtain at first a limpid solution; but if we continue to add crystals, the liquid becomes muddy, drops of oil separate and swim on the surface in a liquid form. When we neutralize the acid, the crystals immediately appear again. Liquid ammonia and caustic soda have no action on these crystals cold; but if we apply heat and agitate, we obtain a muddy liquid, which, on cooling, allows the crystals to subside.

M. Winkler‡ distilled 8 lbs. of cubebs, and obtained 10 ounces of a muddy oil of the consistence of olive oil, having the smell and taste of cubebs. It was filtered with difficulty. It was then quite clear, almost transparent, and had a very light green colour. When left at rest in a close vessel, at the temperature of 41°, it deposited crystals in two days, which gradually increased in number, during three weeks, and indeed did not quite cease to be deposited till after an interval of several months. These crystals, constituting cubeb camphor, when as pure as possible, were found to possess the following characters:—

They were colourless, brilliant, and almost transparent. They belong to the rhomboidal system, and their shape has been determined by the measurements of Mr Brooke. They are soft and easily reduced to powder. The smell is similar to that of cubebs; the taste at first resembles that of cubebs and camphor, but leaves a cooling impression in the mouth.

They melt when heated to about 157°. The liquid is clear, colourless, and of the consistence of olive oil, and has a specific gravity of 0·926. It congeals again (when cooled a few degrees below the melting point) into a crystalline transparent and colourless solid. When heated still higher in a retort, vapours rise, which

* Annals of Philosophy (Second Series), iii. 202.
† Annalen der Pharmacie, ii. 90. ‡ Jour. de Pharmacie, xx. 404.

condense into a fine silky powder. The liquid boils about the temperature of 306°. But the temperature may be raised a good deal higher; it then becomes yellow from partial decomposition, and no camphor sublimes. But if we subject a small quantity of this camphor to a sudden heat, it may be easily sublimed.

When exposed to the flame of a spirit lamp, it does not flame till it begins to be decomposed, and cannot easily be made to continue to burn.

It distils along with water with great difficulty.

Iodine gives it a yellowish-brown colour; when the two substances are mixed, they melt into a thick opaque liquid. Considerable heat is produced.

With chlorine it melts into a clear colourless liquid. Heat is evolved; and if we continue the passage of chlorine gas, a viscid brownish-yellow mass is formed, having an acid smell and taste.

Sulphuric acid acts on it slowly; after some hours, the mixture becomes brown, and smells of sulphurous acid.

Nitric acid decomposes it with the evolution of nitrous gas. The product is a brown resin.

Cubeb camphor combines with sulphur and phosphorus.

This camphor was analyzed by Blanchet and Sell,* who obtained

Carbon	80·12 or 16 atoms	= 12	or per cent.	81·35
Hydrogen	11·42 or 14 atoms	= 1·75	— —	11·86
Oxygen	8·46 or 1 atom	= 1	— —	6·79
	100·00	14·75		100·00

SECTION V.—OF ASARIN.

This substance, which possesses characters analogous to camphor, was obtained by MM. Lassaigne, and H. Feneulle,† by distilling the roots of the *asarum europeum*, or *asarabacca*, with water, after allowing them to macerate during 24 hours.‡ The roots were mixed with 8 times their weight of water, and $\frac{5}{8}$ths of this water were distilled off. The asarin gradually crystallized when the liquid distilled over was left at rest for a couple of days.

But the fullest account of this substance is to be found in the inaugural dissertation of Dr Graeger, *De Asaro Europæo*, published at Göttingen in 1830. The substance of his researches has been given by Blanchet and Sell, in their important paper *on the composition of some organic bodies*.§

Graeger obtained two different crystallized bodies from the root of the *asarum europæum;* one previously distinguished by the name of *camphor from asarum*, or *asarin;* the other new, to which he gave the name of *asarite*.

When asarum root is distilled with water, it furnishes a milky liquid, having an aromatic smell and an acrid taste. On the surface of the liquid, yellow drops may be observed swimming, which are

* Ann. der Pharm. vi. 295. † Jour. de Pharmacie, vi. 561.
‡ Ibid. § Ann. der Pharmacie, vi. 297.

gradually converted into needle-form crystals. These crystals constitute the *asarite*. When separated from the liquid by the filter, they were dissolved in alcohol, and precipitated from that solution by water. They now constituted a brilliant white mass, which floated in the liquid, while a yellow milky liquid was deposited at the bottom. This last assumed the appearance of *manna tabulata*, and was separated from the crystals by decantation and filtration. The crystals, dried between folds of blotting paper, constituted pure *asarite*. The yellow coagulated oily mass was a mixture of volatile oil and asarum camphor. It was melted in a platinum capsule; the oil evaporated, and a white matter (*asarin*) remained behind.

Asarite is in small needles, having a silky lustre. It has neither smell nor taste. Its specific gravity at 158° is 0·95. It melts into a colourless oily liquid. If we continue the heat, it is volatilized in a white vapour, which is very irritating. At a higher temperature it burns with a clear flame, giving out much smoke, and leaves a charcoal very easily incinerated. It sublimes at the commencement of the process unaltered, but the last portions are empyreumatic, and have a yellowish-brown colour, depositing charcoal, without giving out any ammonia.

The crystals are soluble in alcohol, ether, and the volatile oils; but not in water. Nitric acid dissolves them with the evolution of gas, and oxalic acid is formed. Sulphuric acid also dissolves them with the evolution of gas; but if we dilute the solution with water, the asarite separates without alteration. If we heat the sulphuric acid, the solution assumes a brown colour, and the asarite is not thrown down by the addition of water. The liquid becomes gradually blue, and when diluted with a still greater quantity of water, it assumes a wine-red colour. It then becomes violet, and deposits ulmin. M. Graeger supposes that an acid is formed analagous to the althionic or sulpho-naphthalic.

Asarin, or *asarum camphor*, is distinguished from asarite by the following properties:—It may be volatilized without the residue giving out very irritating vapours. Water throws it down from its alcoholic solution in cubes or prisms with six faces. It dissolves in nitric acid slowly, and without the disengagement of any gas. The solution contains oxalic acid. With concentrated sulphuric acid asarin gives a solution of a brownish-red colour, from which water throws down a brown resin. The dilute solution contains a little tannin. When heated it neither becomes blue nor green but reddish-brown. After fusion it has the form of a striated crystalline mass.

Dr Graeger sent a specimen of this camphor to MM. Blanchet and Sell, who found it possessed of the following properties:—

It was perfectly white and transparent, and was crystallized in prisms with six faces. It melted at 104°, and became solid when cooled down to 80°½. It boiled at 536°, and the thermometer during the boiling speedily rose to 572°, at which point the camphor undergoes decomposition. When allowed to cool after boiling it does not become solid till it reaches the temperature of 73°½. It does not sublime.

It was purified for analysis by dissolving it in hot alcohol, and crystallizing it. The alcohol was removed by fusing the crystals. Blanchet and Sell obtained

Carbon	68·645 or 8 atoms	= 6	or per cent.	69·57
Hydrogen	7·730 or 5 atoms	= 0·625	— —	7·24
Oxygen	23·625 or 2 atoms	= 2	— —	23·19
	100·000	8·625		100

It will be seen, in a preceding Section, that the volatile oil of asarum was found by Blanchet and Sell composed of

Carbon	76·36
Hydrogen	9·10
Oxygen	14·54
	100

Blanchet and Sell consider the true formula for the oil to be

8 atoms carbon	= 6	or per cent.	80·00
4 atoms hydrogen	= 0·5	— —	6·66
1 atom oxygen	= 1	— —	13·34
	7·5		100·00

Thus making the asarin a hydrate of the oil. The reason of the want of agreement with this formula in the analysis of the volatile oil, was the quantity of asarin which it held in solution, which of course sunk the carbon, and raised the hydrogen and oxygen somewhat too high.

Leopold Gmelin has collected all the facts scattered through chemical books respecting the camphors obtained from different volatile oils.* He has enumerated no fewer than 32 species. But several of these, *naphthalin* for example, certainly cannot be considered as camphor. I think it useless to insert this catalogue here, till the nature of the various substances, at present called camphor, has been determined by accurate experiments.

The volatile oils are so numerous, that it would be improper to introduce an account of the whole of them here, even if it were possible. M. Raybaut, a perfumer in Paris, has given a table of no fewer than 207 volatile oils prepared by himself, with the names of the plants from which they were obtained, the quantity from a given weight of the plant, and the nature of the oil. To this table, in the *Journal de Pharmacie*, vol. xx., p. 444, we refer such readers as wish for further information on this curious subject. The most productive of the 207 substances was the seeds of cummin, 100 lbs. of which yielded 2·75 lbs. of volatile oil.

APPENDIX.

The following substances, connected with volatile oils, are inserted here, to draw the attention of chemists to their investigation :—

* Handbuch der theoretischen Chemie, ii. 403. Third Edition. 1829.

SECTION I.—OF HELENIN.

This substance, which exists in the root of the *inula helenium*, or *elecampane*, was first noticed by M. Geoffroy, Jun.* It was afterwards examined more in detail by Dr Lewis.† I am not aware that it has been examined by modern chemists.

When the root of elecampane is distilled, the helenin passes with the water under the form of a yellowish oil, which falls to the bottom of the water, and becomes solid. If we digest the root of elecampane in hot alcohol, and set the liquid aside, the helenin is gradually deposited in crystals. It may be purified by distilling it a second time along with water.

The crystals are colourless, and either rectangular prisms or cubes. When sublimed, it is in soft plates, which may be cut with a knife. It is heavier than water. Its taste and smell are similar to those of elecampane root. At 107°½, it melts into an oil, and when the temperature is raised, may be sublimed without alteration.

It is very little soluble in water, whether cold or hot; but very soluble in hot alcohol, but partly falls down in crystals when the liquid cools, and is totally precipitated by water. It is very soluble in ether, and in oil of turpentine. Nitric acid converts it into a resin.

SECTION II.—OF BETULIN.

This substance, which exists in the epidermis of the *betula alba*, or common *birch*, was discovered by Lowitz, who published an account of its properties in 1788,‡ and it has not been since that time made a subject of investigation by modern chemists.

We may obtain it under the form of white lanuginous vegetations when we heat the bark of the birch in the open air till it becomes brown. It is so bulky and light, that 8 or 10 grains of it occupy as much room as a pound of water. When thrown on hot coals it sublimes, giving out an agreeable smell. But when we attempt to distil it in a retort, it is decomposed. When held to a lighted candle, it burns with a white flame.

It is insoluble in water; but it dissolves in 120 times its weight of cold, and 80 times its weight of boiling alcohol. When the alcohol cools it is deposited in capillary crystals. It is soluble in ether, and in the fixed and volatile oils. Sulphuric acid dissolves it; and, when the solution is mixed with water, it concretes and becomes white. Neither the alkaline hydrates nor carbonates dissolve it.

SECTION III.—OF NICOTIANIN.

This concrete oily substance exists in tobacco, and gives it its characteristic odour. It was first obtained by Hermbstadt. Posselt and Reinmann prepare it in the following way:—

Distil a mixture of 6 pounds of tobacco leaves, and 12 pounds of water, till one half of the liquid has passed over. Add to the liquor

* Mem. de l'Acad. Paris, 1721, p. 155. † Lewis's Neumann's Chemistry, p. 420.
‡ Crell's Chemische Annalen, 1788, ii. 312.

6 pounds of water, and distil a second time. Repeat this a third time. On the surface of the liquid which has distilled over, about 11 grains of a fatty substance swims. This is the *nicotianin*.

It has the smell of tobacco smoke, and an aromatic and bitterish taste. Heat volatilizes it. It is insoluble in water, but dissolves readily in alcohol and ether. It is insoluble in the dilute acids, but soluble in caustic potash.*

It was obtained also by O. Henry, and Boutron-Charlard, but not particularly examined.†

SECTION IV.—OF ANEMONIN.

This substance was discovered by M. Robert, and by Vauquelin,‡ in 1820, when the fresh leaves of the *anemone pratensis* were distilled with $2\frac{1}{2}$ times their weight of water, and the distillation was stopped when $\frac{2}{3}$ths of the water had come over. The *anemone pulsatilla* and *nemorosa* yields it also when treated in the same way.§ The liquid thus obtained is put into a retort, and $\frac{1}{8}$th of it is again distilled off. If this last liquid be set aside for some weeks in a cool place, it deposits crystals of *anemonin*.

It crystallizes in six-sided needles. It is heavier than water, and easily reduced to powder. When thrown upon a hot metallic plate, it is volatilized without leaving any residue, emitting at the same time acrid vapours. When distilled it passes over in the form of an oily liquid, which soon becomes solid. A small portion of it is decomposed.

The smell of its vapour occasions tears, and excites a painful sensation in the nostril. At the ordinary temperature of the air it has no smell, and while solid is nearly insipid. But when in a state of fusion it is caustic, and deprives the tongue of sensibility for several days.

It is scarcely soluble in cold water. Boiling water dissolves it, and lets it fall in crystals as the solution cools. Alcohol acts like water. The fixed and volatile oils dissolve it when assisted by heat. The strong acids, and the alkaline hydrates and carbonates decompose it.

According to Schwartz, anemonin, especially that from the *anemone nemorosa*, is mixed with a precipitate, not capable of crystallizing, which is produced by the action of the air on the substances distilled over. This precipitate is a light bulky powder, not volatile, scarcely soluble in water, and insoluble in alcohol and the dilute acids. The alkalies give it a yellow colour, and decompose it into two substances, one of which dissolves in the alkaline liquid, while the other forms with the alkali an insoluble compound.

The first of these substances may be precipitated by an acid from its alkaline solution. Schwartz conceives that this powder is composed of two acids: one, volatile and soluble in boiling water, he calls *anemonic acid;* to the other, which is yellow and insoluble, he has given no name.

Anemonin possesses poisonous qualities, and irritates and inflames the skin.

* Mag. Pharm. xxiv. 138, and xxv. 2, 57. † Jour. de Pharmacie, xxii. 697.
‡ Jour. de Pharmacie, vi. 229. § Schwartz, Mag. Pharm. x. 193, and xix. 168.

CHAPTER IX.

OF RESINS.

THE term *resin* (*resina*, ῥητίνη) was applied by the ancients to certain inspissated juices, from the tribe of pines, which were employed in medicine. Several of them are mentioned by Dioscorides and Pliny, together with the trees from which they exude. They drew but little of the attention of chemists, till about the end of the 17th and beginning of the 18th century. Boyle mentions common rosin; but without any description of its qualities or essential characters. Nor do we find any attempt to specify these characteristic properties in the chemical writings of Lemery, or Stahl, or Boerhaave. Neumann, in his chemical, lectures gives a definition of *resins*, nearly the same as is found in modern chemical works. Of the various investigators of the nature of these bodies, which have appeared in our days, Unverdorben may be mentioned as the person to whom we are indebted for the most elaborate and valuable researches.*

As resins are found in almost all plants, and in almost every part of the plant, it would be an impossible task to undertake to enumerate them all. We must confine ourselves to those which exist in considerable quantity, and which have been applied to purposes of utility. They are obtained either by exudation from trees, or by digesting the substances containing the resin in alcohol. In the first case, they either exude from natural openings, or artificial incisions made through the bark and part of the wood of the tree that yields them. They flow out during summer, in a liquid state, the resin being held in solution by a volatile oil, which, when the exudation is exposed to the air, either makes its escape, or is converted into resin by the absorption of oxygen. When this change takes place, the liquid is converted into a solid resin. In the second case, the alcoholic solution being diluted with water, the resin falls down, and the alcohol is recovered by distilling the diluted liquid. The reader can be at no loss to form a notion of what is meant by *resin*, when he is informed that common *rosin* furnishes a very perfect example of a resin, and that it is from this substance that the whole genus derived its name: for rosin is merely the word *resin*, altered by common use.

Resins may be distinguished by the following properties:—

They are solid substances, naturally brittle; have a certain degree of transparency, and a colour most commonly inclining to yellow. Their taste is insipid, and they have no smell, except when they retain a portion of volatile oil, in which case they partake of the smell and acrid taste of that oil.

* Poggendorf's Annalen, vii. 311—xi. 27, 230, 393—xiv. 116—xvi. 369—xvii. 179, 487—xxi. 172.

They are non-conductors of electricity, and when excited by friction their electricity is negative.

They are heavier than water; but the specific gravity varies considerably even in the same resin at different times. The following table exhibits a view of the specific gravity of such of the resins as have been hydrostatically examined:—*

Jalap resin . .	1·01†
Elemi . .	1·0182
Anime . . .	1·0284
Highgate resin .	1·046‡
Benzoin . . .	1·063 to 1·092
Copal . . .	1·069‡
Tacamahac . .	1·0463
Rosin . . .	1·080‡
Mastich . . .	1·0742
Sandarich . .	1·060‡
Dammora . .	1·097 to 1·123
Lac . . .	1·1390
Dragon's blood .	1·196
Labdanum . .	1·1862
Guaiacum . .	1·2289§

When exposed to heat they melt; and if the heat be increased they take fire, and burn with a strong yellow flame, emitting at the same time a vast quantity of smoke.

They are all insoluble in water whether cold or hot; but when they are melted along with water, or mixed with volatile oil, and then distilled with water, they seem to unite with a portion of that liquid; for they become opaque, and lose much of their brittleness. This at least is the case with common rosin.

They are all, with a few exceptions, soluble in alcohol, especially when assisted by heat. The solution is usually transparent; and when the alcohol is evaporated, the resin is obtained unaltered in its properties. Alcohol, according to Tingry, never takes up more than $\frac{1}{3}$d of its weight of resin. When the solution is mixed with water, it becomes milky, and the resin falls in a state of a white powder. They are soluble also in sulphuric ether.

Several of them are soluble in fixed oils, especially in the drying oils. The greater number are soluble in the volatile oils; at least in oil of turpentine, the one commonly employed.

Mr Hatchett first examined the action of fixed alkalies on resins, and showed that alkaline leys dissolve them with facility. He reduced a quantity of common rosin to powder, and gradually adding it to a boiling lixivium of carbonate of potash, a perfect solution was obtained of a clear yellow colour, which continued permanent after

* The specific gravities in the text were ascertained chiefly by Brisson and by myself. The older writers differ so much from each other, that there is reason to suspect that the substances tried were not always those to which we at present give the same names.

† Unverdorben. ‡ By my trials. § Brande.

long exposure to the air. The experiment succeeded equally with carbonate of soda, and with solutions of pure potash or soda. Every other resin tried was dissolved as well as *rosin*. The well-known fact that the soap-makers in this country constantly mix *rosin* with their soap; that it owes its yellow colour, its odour, and its easy solubility in water to this addition, ought to have led chemists to have suspected the solubility of resins in alkalies. No such consequence, however, was drawn from this notorious fact.

These alkaline solutions of resins have the properties of soap, and may be employed as detergents. When mixed with an acid, the resin is separated in flakes, usually of a yellow colour, and not much altered in its nature. From the experiments of Unverdorben, it is evident that several of the resins have the properties of acids.

Ammonia acts but imperfectly upon resins, and does not form a complete solution of most of them. But Unverdorben has shown that ammoniacal gas is absorbed by resins, and a neutral compound formed.

It was the received opinion of chemists that acids do not act upon resins. This opinion seems to have been founded on the known effect of nitric acid upon oils, and on the old theory derived from that action, that resins are compounds of an oil and an acid.* Mr Hatchett first ascertained this opinion also to be erroneous, and showed that most of the acids dissolve resins with facility, producing different phenomena according to circumstances.

When sulphuric acid is poured upon any of the resins in powder it dissolves them in a few minutes. At first the solution is transparent, of a yellowish-brown colour, and of the consistency of a viscid oil, and the resin may be precipitated nearly unaltered by the addition of water. If the solution be placed on a sand bath, its colour becomes deeper, sulphurous acid gas is emitted, and it becomes very thick, and of an intense black.† If the solution, some time after it is completed, and before it has acquired the deep black colour, be edulcorated, and the residuum digested in alcohol, and the alcohol afterwards separated by distillation, the residue is in part soluble in cold water, and the portion dissolved possesses the properties of artificial tannin.‡ Thus it appears, that sulphuric acid dissolves resins, but gradually acts upon them after the solution is completed, converting them first into artificial tannin, and afterwards reducing them to charcoal; for the last black state of the solution is owing to the evolution of this substance. The charcoal thus formed is dense, and burns rather like mineral than vegetable coal. Its quantity is also very considerable. The following table exhibits a view of the proportion of charcoal obtained by Mr Hatchett, by digesting different resins in sulphuric acid, edulcorating the residue, and separating the tannin by means of alcohol and water.§ The quantity of resin employed was always 100 grains.

* See Hoffmann, Observ. Phys. Chim. Select. p. 55.

† Hatchett on an Artificial Tanning Substance, Phil. Trans. 1805.

‡ Hatchett's Third Series of Experiments, ibid. 1806.

§ Hatchett, ibid.

Copal	67
Mastich	66
Elemi	63
Tacamahac	62
Amber	56
Rosin	43

The quantity of charcoal formed by this process is very remarkable. The same substances, when charred in the usual way by exposure to a red heat in close vessels, yield very little charcoal. The following table exhibits the quantity obtained by Mr Hatchett from 100 grains of several of them :—*

Mastich	4·50 grains.
Amber	3·50
Rosin	0·65

Nitric acid likewise dissolves the resins with facility, but not without changing their nature. Mr Hatchett was first led to examine the action of this acid on resins, by observing that resins are thrown down by acids from their solutions in alkalies in the state of a curdy precipitate ; but when nitric acid is added in excess, the whole of the precipitate is redissolved in a boiling heat. This remarkable fact, which did not hold when sulphuric or muriatic acids were used, led him to try whether the resins were soluble in nitric acid. He poured nitric acid of the specific gravity 1·38, on powdered rosin in a tubulated retort; and by repeated distillation formed a complete solution of a brownish-yellow colour. The solution took place much sooner in an open matrass than in close vessels. The solution continues permanent, though left exposed to the air. It becomes turbid when water is added ; but when the mixture is boiled, the whole is redissolved. When Mr Hatchett collected the precipitate thrown down by water by filtration, he found that it still possessed several of the properties of resin. The resin is thrown down from nitric acid by potash, soda, and ammonia; but an excess of these alkalies redissolves the precipitate, and forms brownish orange-coloured liquids. When Mr Hatchett dissolved resin in boiling nitric acid, the solution was attended with a copious discharge of nitrous gas ; and when the powdered resin was thrown into cold nitric acid, a considerable effervescence soon took place, and a porous mass was formed, commonly of a deep orange colour.

When the digestion of nitric acid upon a resinous substance is continued long enough, and the quantity of acid is sufficient, the dissolved resin is completely changed; it is not precipitated by water; and by evaporation a viscid substance of a deep-yellow colour is obtained, equally soluble in water and alcohol, and seemingly intermediate between resin and extractive.† If the abstraction of nitric acid be repeated, this substance gradually assumes the properties of artificial tannin.‡ Thus it appears that nitric acid gradually alters

* Hatchett's Third Series of Experiments, Phil Trans. 1806.

† Hatchett on an Artificial Tanning Substance, Phil. Trans. 1805.

‡ Hatchett's Additional Experiments on Artificial Tannin, Phil. Trans. 1805.

the nature of resin, producing a suite of changes which terminate in artificial tannin, upon which nitric acid has no action.

Muriatic acid and acetic acid dissolve resin slowly, and it may be precipitated again from them unaltered. Mr Hatchett, to whom we are indebted for the knowledge of all these solutions, recommends acetic acid as an excellent solvent of resins for vegetable analyses. He employed it himself with much address in his analysis of the different varieties of lac.*

When resins are subjected to destructive distillation, we obtain, according to Gren, carburetted hydrogen and carbonic acid gas, a very small portion of acidulous water, and much empyreumatic oil. The charcoal is light and brilliant, and contains no alkali.†

When volatile oils are exposed for some time to the action of the atmosphere, they acquire consistency, and assume the properties of resins. During this change they absorb a quantity of oxygen from the air. Westrumb put 30 grains of oil of turpentine into 40 cubic inches of chlorine gas. Heat was evolved; the oil gradually evaporated, and assumed the form of yellow resin.‡ Mr Proust observed, that when volatile oil is exposed to the air, it is partly converted into a resin, and partly into a crystallized acid; usually the benzoic or the camphoric. Hence we see that the oil is converted into two distinct substances. During this change oxygen is absorbed; and Fourcroy has observed that a portion of water is also formed.§ It is probable, from these facts, that resin is volatile oil deprived of a portion of its hydrogen, and combined with oxygen.

All the resins have not the same tendency to unite with bases. Some indeed, seem to want that property altogether. Unverdorben has divided them into four classes.

1. *Strongly acid resins.* They dissolve readily in caustic ammonia. And the saturated ammoniacal solution may be boiled for a quarter of an hour without letting the resin precipitate. When the solution is evaporated we obtain a super-resinate of ammonia.

2. *Resins moderately acid.* They dissolve at the usual temperature of the air in ammonia; but when the solution is boiled for a quarter of an hour it is completely decomposed, the ammonia being driven off and the resin precipitated. The ammoniacal compounds of these resins are usually less soluble in water than those of the first class. But their acid properties are sufficiently strong to enable them to be precipitated from alcohol by an alcoholic solution of acetate of copper, and to dissolve by the assistance of a boiling heat in carbonate of soda, from which they drive off the carbonic acid.

Both the resins of the first and second class, when dissolved in alcohol, redden litmus paper.

3. *Resins feebly acid.* They are neither soluble in caustic ammonia, nor in boiling carbonate of soda; but they dissolve in caustic

* Phil. Trans. 1804.
† Handbuch, ii. 140.
‡ Crell's Annals, i. 1790.
§ Fourcroy, viii. 16.

potash and soda. Their alcoholic solution is not precipitated by acetate of copper, but it is by an alcoholic solution of acetate of lead. The alcohol solutions of the resins belonging to this class do not redden litmus paper.

4. *Neutral resins.* They are not soluble in caustic potash or soda. But some of them dissolve in a solution of potash saturated with another resin. They generally precipitate when we add to the liquid an additional dose of caustic potash.

So far as experiment has gone, the resins are all combinations of carbon, hydrogen, and oxygen. But the facts ascertained respecting these constituents will come in better when treating of the particular resins to which they refer, than they would do here.

In describing the resins it will be convenient to divide them into two sets, namely, *semifluid resins*, or *balsams*, as they have been called, and *solid resins.*

DIVISION I.—BALSAMS.

The balsams owe their semifluidity to a certain quantity of volatile oil which they contain. It may in general be separated by distillation, and then the solid resinous body remains behind. The most important of the balsams are the following:—

1 Turpentine.
2 Copaiva.
3 Balsam of Tolu.
4 Balsam of Peru.
5 Styrax.
6 Opobalsamum.
7 China varnish.

Let us take a view of these balsams in the order in which they have been named.

SECTION I.—OF TURPENTINE.

The name turpentine has been given to a semifluid resinous body which exudes from various species of the *pinus*. Its properties differ according to the species of pine, the age of the tree, the time of the year when it is collected, and the climate in which the tree vegetates. But the great constituents of it are always *colophan*, or *common rosin*, and oil of turpentine.

(1.) *Common turpentine* is extracted by incision from the *pinus abies*, or *spruce fir*, and the *pinus sylvestris*, or *Scotch fir*. It is thick, viscid, and has a greyish-yellow colour, a very slight smell of oil of turpentine, and a bitter burning taste.

It is composed, as Unverdorben has shown, of a volatile oil, *oil of turpentine*, and two resins which he has distinguished by the names of *pinic* and *silvic* acids. Berzelius calls them *resin alpha*, and *resin beta* of turpentine.

The volatile oil varies from 5 to 25 per cent. of the turpentine. The two resins are no less various in their quantity. Unverdorben separated these three substances from each other in the following way:—The turpentine was mixed with water, and distilled to separate the oil. The residue was dried and reduced to powder,

and digested in alcohol of 0·867 specific gravity. It dissolves the *pinic acid*, but leaves the *silvic*. At the same time with the pinic acid the alcohol dissolves a small quantity of *neutral resin*, which may be called resin *c*. If we pour into this alcoholic solution an alcoholic solution of acetate of copper, the pinic acid is precipitated in combination with the oxide of copper. If we evaporate the alcohol and dilute it with water, the resin *c* precipitates.

1. The properties of oil of turpentine have been detailed in the preceding Chapter.

2. The properties of pinic acid have been given in detail in the work on the *Chemistry of Inorganic Bodies* (vol. ii. p. 145). The *pinates*, or combinations of this substance with the alkalies, may be obtained by digesting an ethereal solution of pinic acid over the alkaline carbonates. The carbonic acid is driven off, and the alkaline pinate dissolves in the ether. The earthy carbonates, with the exception of carbonate of magnesia, are not decomposed by this process. But the carbonic acid is driven off and a pinate formed, when we mix the carbonates of the earths with fixed pinic acid, or when we boil a solution of pinic acid in oil of turpentine over them. The greater number of these pinates dissolve both in melted pinic acid, and likewise in an alcoholic solution of that resinous acid, even when the salt is insoluble in pure alcohol. It is probable that in these cases a bipinate of the base is formed. The pinates, with bases of metallic oxides, may be obtained by double decomposition. We must drop the metalline salt very slowly and cautiously into the alkaline pinate. If we adopt the opposite method by dropping the alkaline pinate into the metalline salt, the precipitate is mixed with a quantity of subpinate of the metalline base. These double decompositions may be made by dissolving the salts, when that is practicable, in water, and when not, in alcohol.

The pinates formed by Unverdorben, who has alone examined them, have been described in the *Chemistry of Inorganic Bodies*, while treating of the salts.*

3. That portion of the resin which remains undissolved when the turpentine freed from its oil is digested in cold alcohol of 0·867, has been called *silvic acid* by Unverdorben, and *resin beta* by Berzelius. It is not quite free from pinic acid. To obtain it pure, dissolve it by boiling in twice its weight of alcohol of 0·867, and filter the solution while hot. During the cooling the silvic acid falls down in crystals, but still retains about 4 per cent. of pinic acid, from which it may be freed by repeated crystallizations. Its properties have been described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 149); and the salts which it forms, in the Chapter in the same work on the salts, have been enumerated and described, as far as they have been examined by Unverdorben.

Henry Rose has concluded that silvic acid is a compound of 1

* See vol. ii. pp. 400, 440, 469, 492, 524, 539, 547, 577, 585, 595, 602, 609, 621, 649, 677, 686, 693, 699, and 713.

atom oil of turpentine and 1 atom oxygen, or that it consists of $C^{10} H^8 O$.* But Trommsdorf analyzed it, and obtained

Carbonic acid . . .	78·73
Hydrogen	9·80
Oxygen	11·47
	100·00†

If we adopt the formula of Rose, we get

10 atoms carbon	= 7·5	or per cent.	78·94
8 atoms hydrogen	= 1·0	— —	10·53
1 atom oxygen	= 1·0	— —	10·53
	9·5		100

Trommsdorf considers the composition to be $C^{10} H^{7\frac{1}{2}} O$, a formula which comes nearer the result of his analysis, and which was confirmed by a subsequent analysis of Liebig.

But from the analysis of silvate of copper, Trommsdorf reckons the atomic weight of silvic acid 37·75 = 4 ($C^{10} H^{7\frac{1}{2}} O$). This gives us the composition

40 carbon	= 30	or per cent.	79·4
30 hydrogen	= 3·75	— —	9·9
4 oxygen	= 4	— —	10·7
	37·75		100

(2.) *Venice turpentine* comes from Styria, Hungary, and the Tyrol, and is extracted from the *pinus larix*, or *common larch*. It is limpid, transparent, and has a light-yellow colour, and the consistence of honey. Its smell is disagreeable, and its taste bitter and hot. It must be many years exposed to the air before it becomes hard and brittle. It contains from 18 to 25 per cent. of oil of turpentine, which is extracted by distilling it with water. What remains is *colophan*, or common *rosin*.

Venice turpentine dissolves slowly in alcohol, without leaving any residue. The caustic alkalies dissolve it easily, and no doubt combine with its acid resins. If Venice turpentine be mixed with caustic potash ley it dissolves, while a white flocky matter precipitates. The solution is limpid and yellowish-brown. Its taste is not alkaline, and it may be evaporated in a gentle heat without any oil being disengaged. When evaporated till it becomes solid it is opaque and wrinkled. It dissolves readily in water, but separates when we pour into the solution a certain quantity of carbonate or hydrate of potash. Soda acts precisely in the same manner with this turpentine as potash.

Very concentrated ammonia has little action on Venice turpentine, but when diluted it dissolves the greater part of the turpentine by the assistance of heat. The undissolved portion assumes the appearance of a gelatinous mass, and the solution has a yellow-

* Poggendorf's Annalen, xxxiii. 42. † Ann. der Pharmacie, xiii. 171.

ish-brown colour. On cooling the whole concretes into a gelatinous solid, while a brown liquid separates, which may be decanted off. When this mass is mixed with water it becomes white. When agitated in from 40 to 50 times its weight of water it forms a milky liquid, which in about 12 hours concretes into a white soft jelly. The turpentine thus treated is divided into two substances, which have distinct properties.

a. The limpid, yellow liquid which separates from the jelly before and after the dilution, and which passes through the filter, is a combination of ammonia with a resin, which contains no volatile oil. If we saturate it with an acid the resin precipitates in powder, and may be collected and washed on a filter. It is a white, light, friable matter, with an earthy fracture. It melts at the temperature of boiling water, or a little higher, and then has the appearance of common rosin. When assisted by a boiling temperature, naphtha dissolves a portion of this resin, and assumes a brown colour; but during the cooling the resin precipitates, and the naphtha becomes colourless as at first.

b. The gelatinous part of the combination of ammonia and Venice turpentine, when dried in the open air, has a yellow colour, is transparent and adhesive like the turpentine itself. It consists of the ammonia combined with a resin, and with oil of turpentine. In proportion as the ammonia is driven off, the turpentine is regenerated, but it is softer than before, because it contains less resin. By mixing it with acidulated water and distilling, the oil is removed, and a resin remains, which differs from the resin in the liquid portion in being soluble in naphtha.

A solution of turpentine in potash precipitates the salts which have the alkaline earths, and the metallic oxides for bases. These precipitates are insoluble in water, and when distilled with water after having been dried, they give off oil of turpentine. They have no smell, and seem at first destitute of taste, but by degrees the acrid taste of oil of turpentine becomes perceptible.

Unverdorben analyzed fresh Venice turpentine, and obtained: 1. A volatile oil easily distilled off. 2. An oil not so easily distilled, and having a great tendency to be converted into a resin. 3. Succinic acid, which is found dissolved in the water with which the turpentine is boiled, in order to drive off the volatile oil. 4. Three different resins, which were separated in the following manner:—The turpentine freed from its oils was dissolved in alcohol of 0·873, and the solution was precipitated by an alcoholic solution of acetate of copper. This precipitate consisted chiefly of pinate of copper mixed with a very small quantity of silvate of copper. These two acid resins were separated in the way already stated. The solution, which had been precipitated by acetate of copper, was evaporated to dryness, the acetate of copper which it contained was dissolved out by water, and the resin taken up by alcohol of 0·873, which left, without dissolving it, a small quantity of pinate of copper. When the alcoholic solution is evaporated to dryness,

the third resin remains. It is colourless, and has a strong resinous lustre. It is insoluble in alcohol and naphtha, and belongs to the class of neutral resins.

(3.) French turpentine is obtained from the *pinus maritima*, which grows in the south of France. It resembles Venice turpentine, and is considered as possessed of nearly the same qualities.

When turpentine is kneaded with $\frac{1}{12}$th of its weight of *magnesia alba*, a combination takes place gradually, and after six or seven days the mixture becomes firm. Fauré, who first observed this effect, has recommended this combination as a convenient mode of administrating turpentine internally as a medicine.* This properly belongs to the turpentine from the *pinus maritima*, but not to that from the *pinus picea*.†

(4.) *Strasburg turpentine* is extracted from the *pinus picea*. It is pale yellow, transparent, and more liquid than Venice turpentine, and has a smell which is rather agreeable. It has been subjected to an interesting examination by M. Caillot. According to him it is obtained not only from the *pinus picea*, but also from the *pinus abies*.‡

When he distilled off the volatile oil along with water, he found that the water contained in solution a quantity of succinic acid. He digested it in boiling water till every thing soluble in that liquid was taken up. He then treated it with cold absolute alcohol, which left undissolved a neutral resin. It is colourless, and is insoluble in cold alcohol, in naphtha, and in caustic potash. It differs by its insolubility in alcohol from the neutral resin in Venice turpentine.

The alcoholic solution being evaporated, left a resinous mass, which was boiled in a solution consisting of twice its weight of carbonate of potash. The mixture was concentrated by evaporation, and the alkaline liquor decanted off. The residual compound of resin and potash was mixed with from 25 to 30 times its weight of water, and the whole left at rest. There was deposited at the bottom of the vessel a mass of crystals. This mass, freed from the liquid in which it was deposited, was dissolved in alcohol, and the solution was left to spontaneous evaporation. The resin was deposited in pyramidal crystals, to which Caillot gave the name of *abietin*. It is destitute of smell, and has little taste. It is very fusible, and becomes soft when exposed to the direct rays of the sun. When in a state of fusion, it is colourless and limpid, and looks like melted tallow. On cooling it concretes into a white, opaque, crystalline mass. It is insoluble in water; but dissolves readily in alcohol of 0·833, and in every proportion at a boiling heat. It is soluble in ether, in naphtha, and in concentrated acetic acid, and crystallizes when these liquids are volatilized. It is insoluble in potash.

The resin dissolved by the alkaline carbonate appears to be a mixture of pinic and silvic acids. Caillot has given it the name of

* Jour. de Pharmacie, xvii. 102. † Ibid. p. 106

‡ *Abies excelsa* of Decandolle.

abietic acid. The following table exhibits the result of Caillot's analysis of two different varieties of turpentine :—

	Turpentine from abies pectinata.	Do. from abies excelsa.
Volatile oil . .	33·50	32·00
Pinic and silvic acids .	46·39	45·37
Abietin . . .	10·85	11·47
Abietic acid . .	6·20	7·42
Succinic acid and extract	0·85	1·22
	97·79	97·48

Blanchet and Sell analyzed turpentine from the Vosges which exudes from the *pinus picea*, and obtained

Volatile oil	33·5
Resins	63·44
Extractive and succinic acid .	0·85
	97·79*

Caillot is of opinion that the *abietic* acid belongs particularly to Decandolle's genus *abies;* that is, to the species of pinus which have the summit of the cones pointing upwards.

(5.) *Turpentine from the Carpathian mountains and from Hungary.* The first of these is obtained from the *pinus cembra*, the second from the *pinus mugos.* They resemble Strasburg turpentine very closely.

(6.) *Canada balsam.* Obtained from the *pinus canadensis* and *balsamea.* It has a pale-yellow colour, is transparent, fluid, but adhesive and capable of being drawn out into threads. Its smell is much more agreeable than that of turpentine in general.

(7.) *Turpentine of Cyprus and Chio.* It is extracted from the *pistacea terebinthus.* It is yellow, greenish or bluish green, translucent, viscid, and of the consistence of honey. Its smell is agreeable, and its taste is less acrid than that of any of the preceding varieties. It is often adulterated by being mixed with the cheaper turpentines.

SECTION II.—OF COPAIVA.†

This balsam, which is a good deal used in medicine, comes from Brazil, and from the Antilles. It is obtained not only from the *copaifera officinalis;* but from the *copaifera coriacea, Langsdorfii* and *multijuga*, which grow in the same tract of country with the *officinalis.* It exudes from incisions made in the trunk of the tree. The juice thus obtained is transparent, of a yellowish colour, an agreeable smell, a pungent taste, at first of the consistence of oil, but it gradually becomes as thick as honey. Its specific gravity is 0·950.‡ When mixed with water and distilled, there comes over with the water a very large portion of volatile oil. Lewis obtained

* Jour. de Pharmacie, xx. 224. † *Copahu* of the French.
‡ Schonberg, Gehlen's Jour. vi. 494.

half the original weight of this oil.* Schonberg, from 8 ounces of copaiva, obtained $3\frac{1}{4}$ of oil by this process.† It was colourless, very limpid, of the specific gravity 0·900; had the taste and smell of copaiva, but rather stronger. It dissolved in 8 parts of alcohol; but the copaiva itself is a good deal more soluble.‡ The oil ceases to come over before all the water has passed into the receiver. The residuum, of course, consists of two substances; namely the watery portion, and a greyish-yellow substance, lying at the bottom of the vessel, which, on exposure to the air, dries, and becomes brittle and transparent. When heated it melts, and possesses the characters of a resin. When distilled it yielded a yellowish thick oil, some acidulous water, and a gas; $\frac{1}{6}$th of which was carbonic acid, and the remainder seemed to possess the characters of olefiant gas.§ From these facts, which have been long known, it was concluded, that copaiva is a compound of a resin and a volatile oil, which passes over at a heat inferior to that of boiling water; but the experiments of Schonberg have rendered it much more probable, that the balsam is decomposed when distilled along with water, and that both the oil and resin are new products.

When distilled on a water-bath, nothing comes over but a few drops of water, and 1 or 2 drops of oil.‖ If the vessel be kept at a temperature between 234° and 257°, scarcely any thing more is obtained than when the distillation is conducted over a water-bath. At the temperature of 504° the balsam begins to boil gently, a gas is extricated, and drops begin to pass more rapidly into the receiver. At 550° it boils briskly, and the distillation goes on rapidly. There passes into the receiver a limpid yellowish oil, occasionally mixed with a drop or two of water. As the distillation proceeds the oil becomes more and more yellow. At this period the balsam is as liquid as water, and boils without any frothing or swelling. After this period the oil becomes yellow, and then brownish-red; but still continues pretty thin. The first oil obtained by Schonberg from 8 ounces of copaiva, by this process, was $3\frac{1}{16}$ ounces. The water had a sour taste, and reddened litmus paper. The gas amounted to 81 ounce measures; $\frac{1}{9}$th of it was carbonic acid, the rest resembled olefiant gas.¶

More lately it has been subjected to a new examination by Stoltze,** who has ascertained the following facts:—

It is insoluble in water, yet it communicates to that liquid the peculiar taste and smell by which it is characterized. It dissolves in all proportions in absolute alcohol. Alcohol of 0·812 dissolves a great proportion of it, while alcohol of 0·848 dissolves only the tenth or ninth of its weight of it. It dissolves in all proportions in ether, fixed and volatile oils.

When a small quantity of alcohol, not weaker than 0·812, is poured upon balsam of copaiva, mixed with a fixed oil, the oil does

* Neumann's Chem. p. 285. † Gehlen's Jour. vi. 494.
‡ Schonberg, Gehlen's Jour. vi. 494. § Ibid. 497. ‖ Ibid. 495. ¶ Id. Ibid.
** Berlin Jahrb. xxvii. 2, 179.

not separate, but it is disengaged when a considerable portion is added. Schweitzer has shown that the presence of a fixed oil in this balsam may be detected by agitating it with caustic ammonia. The ammonia becomes milky only if the oil be present.*

Balsam of copaiva unites when heated with sulphur and phosphorus. Sometimes it dissolves as much as half its weight of sulphur. Both of these bodies are thrown down by absolute alcohol. Balsam of copaiva absorbs chlorine gas, becomes muddy, and muriatic acid is formed. Iodine is dissolved in it by the assistance of heat, giving it a dark red colour. It combines with sulphuric acid, assuming a red or brown colour, while sulphurous acid is disengaged.† The balsam becomes viscid.

Concentrated nitric acid attacks it violently. Dilute acid has less action; but transforms it into a hard yellow resin, a portion of which dissolves in the acid at the same time, with a yellow bitter substance soluble in water and in alcohol. Muriatic acid gives copaiva a red colour, but scarcely dissolves it. It may be mixed with concentrated acetic acid, but it becomes muddy, and allows an aqueous liquid to fall to the bottom, while the balsam, dissolved in anhydrous acid, swims on the surface. Boracic, succinic, and benzoic acids are dissolved in small quantities by this balsam. The best way is to dissolve them in absolute alcohol, mix the solution with the balsam, and then evaporate the liquid to drive off the alcohol. Aqueous solutions of oxalic and tartaric acids dissolve a little of this balsam.

Balsam of copaiva combines readily with the salifiable bases. When we mix 3 parts of balsam with a solution containing $\frac{1}{8}$th of its weight of hydrate of potash, a complete combination takes place with the disengagement of heat, and we obtain a limpid liquid. If we add an additional dose of potash, the liquid becomes muddy, and a still greater quantity causes the combination of the balsam and potash to separate and swim on the surface. This compound dissolves in water, and when left to itself a small quantity of neutral resin precipitates. In spirit of wine this compound forms a limpid solution; but the solution of it in absolute alcohol is muddy. It is soluble in ether, and also in a great measure in naphtha.‡ It cannot be dried completely without undergoing decomposition.

With soda it exhibits the same phenomena as with potash.

The same remark applies to ammonia. 1 part of liquid ammonia, of specific gravity 0·96, mixed with 8 parts of balsam, forms a limpid liquid.§ When we double the quantity of ammonia, the liquid

* Poggendorf's Annalen, xvii. 487.

† In France copaiva is often adulterated with castor oil. This adulteration M. Planche has shown may be detected by means of sulphuric acid. A few drops of pure copaiva, mixed with the same quantity of acid, assume a yellow colour, which persists for some time. But if castor oil be present, the yellow colour becomes immediately weak, and speedily disappears. See Jour. de Pharmacie, xi. 231.

‡ See Gerber, Jour. de Pharmacie, xvi. 74.

§ The solubility of copaiva in ammonia seems to have been first noticed by M. Planche. See Jour. de Pharmacie, xi. 228.

begins to get muddy, and if we increase the quantity of ammonia still farther, a separation of the liquid takes place into two portions.* It is then unctuous, soluble in weak alcohol and in ether; but almost insoluble in absolute alcohol, and in the fixed oils. Schweitzer found that when 9 parts of copaiva are agitated in 2 parts of liquid ammonia, of the specific gravity 0·95, and then left at the temperature of 50°, crystals of a neutral resin are gradually deposited. If we wash these crystals in ether, and dissolve them in alcohol, we obtain larger, but less regular crystals. They are white and translucent. They are four-sided prisms, very nearly rectangular, the angles being 90° 30′ and 89° 30′. The acute edge of the prism is usually replaced by a tangent plane.† They are at first soft, but by exposure to the air become hard and brittle, without losing their transparency. They contain no ammonia.‡

With the other salifiable bases balsam of copaiva forms insoluble compounds, which may be obtained by double decomposition. They have the consistence of plaster; their smell is analagous to that of the balsam; they are little soluble in absolute alcohol; but they dissolve in ether, naphtha, and the volatile oils. They are soluble also in balsam of copaiva, and increase its consistence.

The affinity of magnesia for this balsam is remarkable. 1 part of magnesia dissolves in 30 parts of balsam, into a transparent liquid. When we agitate balsam of copaiva with a solution of a metallic subsalt, it combines with the excess of base, and the salt, held in solution by water, becomes neutral. The following table shows the composition of this balsam, as determined by Stoltze and Gerber:§—

	Stoltze.	Gerber.	
		Fresh Balsam.	Old Balsam.
Volatile oil . .	45·59	41	31·70
Yellow hard resin .	52·75	51·38	53·68
Brown soft resin .	1·66	2·18	11·15
Water . . .	— —	5·44	4·10
	100·00	100	100·63

According to Durand, the balsam contains besides a fatty substance, which remains when we dissolve it in a sufficient quantity of alcohol of 0·842. It is insoluble in ether and in absolute alcohol.

1. The volatile oil is not easily obtained from the balsam by distillation. When we distil with water, we must repeat the process seven or eight times, in order to procure all the oil. If we distil the oil alone, it does not come over till the balsam is heated to 500°. But, according to Ader, we may separate the oil without having recourse to distillation. If we agitate 100 parts of alcohol, of 0·836, with

* See Gerber, Jour. de Pharmacie, xvi. 75. † Poggendorf, xvii. 489.
‡ Ibid. xxi. 172. § Jour. de Pharmacie, xvi. 79 and 367.

100 parts of balsam of copaiva, add 37½ parts of caustic alkali of the strength used by the soap-maker, agitate strongly, and pour the whole into 150 parts of water, the oil separates by little and little, and may be decanted off.

This oil is transparent, slightly yellow, and has a specific gravity of 0·880. It is soluble in alcohol. It dissolves caoutchouc without destroying its elasticity. It appears to contain no oxygen, for potassium may be kept in it without losing the metallic lustre. Such are its properties, when obtained by simple distillation from the balsam.

This oil was analyzed by Blanchet, who obtained

Carbon	86·89
Hydrogen	11·70
	98·59

This gives the formula

10 atoms carbon	= 7·50	or per cent.	88·23
8 atoms hydrogen	= 1·0	— —	11·77
	8·5		100·00

This oil boils at 473°. Tin melts in it with great facility. When obtained by distillation with water it is limpid and colourless, has an acrid taste, and the smell of copaiva. It reddens litmus paper, and has a specific gravity of 0·91, but becoming 0·96 by keeping. Dissolves in all proportions in absolute alcohol, ether, and bisulphuret of carbon. It combines with chlorine and iodine. Nitric acid converts it into a resin. Acetic, oxalic, succinic, benzoic, and hydrocyanic acid combine with it. It absorbs muriatic acid, and crystals of artificial camphor are formed. These crystals have been examined by Blanchet*. They have no smell. They are insoluble in cold water and cold alcohol, but slightly soluble in hot alcohol. They easily melt and congeal again, when cooled down to 129°. They boil at 365°, but at that heat they are destroyed, and cannot be sublimed. They are not altered by cold fuming sulphuric acid, but that acid dissolves them when hot, and muriatic acid gas is evolved. These crystals were found composed of

Carbon	57·17 or	10 atoms	= 7·5	or per cent.	57·14
Hydrogen	8·73 or	9 atoms	= 1·125	— —	8·58
Chlorine	33·50 or	1 atom	= 4·5	— —	34·28
	99·40		13·125		100·00

But one of the atoms of hydrogen was united to the chlorine, which was in the state of muriatic acid. So that the crystals are composed of

10 atoms carbon . . .	7·5
8 atoms hydrogen . . .	1·0
	8·5

* Ann. der Pharmacie, vii. 158.

They are, therefore, identical in composition with oil of turpentine, and oil of copaiva.

2. The yellow brittle resin is obtained by digesting the residuous matter after distilling off the oil in naphtha. After evaporating off the naphtha, the yellow resin remains. It has an amber yellow colour, is hard and brittle, and still retains a slight smell of balsam of copaiva. It is soluble in alcohol, ether, volatile and fixed oils, and also in bisulphuret of carbon. It possesses moderately acid properties, similar to those of the silvic acid of Unverdorben. Its alcoholic solution precipitates the alcoholic solutions of acetates of zinc, copper and lead, and of protochloride of tin. It is slightly soluble in sulphuric, nitric and acetic acids, and precipitated from these solutions by water. Nitric acid acts upon it in the same way as upon the balsam itself. It forms with the salifiable bases compounds analogous to those produced by the balsam itself. Its combinations with the alkalies are soft and unctuous, and precipitate when we pour an excess of alkali into the solution. With the earths and metallic oxides, it gives insoluble combinations, which may be dried and reduced to powder. All these combinations are soluble in ether, and more or less so in alcohol; though this liquid generally renders the ethereal solutions muddy. Several of the salts of this resin dissolve in oil of turpentine.

3. The soft brown resin remains behind when the yellow resin is dissolved in naphtha. Old balsam contains much more of it than new, while the quantity of volatile oil is proportionally diminished. From this it would seem to be formed at the expense of the volatile oil. It is always soft and unctuous, and dissolves readily in absolute alcohol, and in ether. Dilute alcohol and naphtha only dissolve it when assisted by heat. It is very soluble in the fixed and volatile oils; but seems to have little affinity for the salifiable bases.

A white crystallized resin may also be obtained from copaiva. The crystals are oblique four-sided prisms, and when small are transparent. They dissolve readily in boiling alcohol, and crystallize again as the solution cools. They redden vegetable blues, combine with bases and form salts. Analyzed by M. H. Rose, they furnished

Carbon	78·16	or 10 atoms	= 7·5	or per cent.	78·94
Hydrogen	10·13	or 8 atoms	= 1	— —	10·53
Oxygen	11·71	or 1 atom	= 1	— —	10·53
	100·00*		9·5		100·00

H. Rose analyzed the combination of this resin with oxide of silver, and obtained

Oxide of silver . .	27·68 or 14·5
Resin . . .	72·32 or 37·88
	100·00

* Poggendorf's Annalen, xxxiii. 35.

If the salt be neutral, it is clear that the resin is a compound of 4 (C^{10} H^{8} O) and that its atomic weight is 38. But it is more probable that the salt contains two atoms of the acid resin. On that supposition its atomic weight will be 19, and its constitution 2 (C^{10} H^{8} O).

The resinate of lead was composed of

Oxide of lead . .	27·525 or 14
Resin . . .	72·475 or 36·86
	100·000

The resinate of lime was found composed of

Lime . . .	8·32 or 3·5
Resin . . .	91·68 or 38·56
	100·00

All these give the atomic weight about 38, if we suppose the salt neutral; or 19, if we admit two atoms of the resin to one atom of base.

Copaiva is sometimes adulterated by fixed oils. Their presence may be detected by alcohol, which dissolves the balsam but leaves the oil. Castor oil however is soluble in alcohol. Its presence may be detected by agitating it in a glass tube with ammonia of 0·965. The solution is transparent if the balsam be pure; but milky if it contains castor oil.

SECTION III.—OF BALSAM OF PERU.

This balsam is obtained from the *myroxylon peruiferum*, which grows in the warm parts of South America.

Two varieties of it occur in commerce. One of these is obtained by incisions made in the tree. It is nearly colourless, having only a slight tint of yellow. Its taste is acrid, but its odour agreeable, analogous to that of storax or benzoin. Alcohol dissolves it completely; but when treated with ether, a white substance is left behind. By exposure to the air its colour deepens, it becomes reddish-brown, and so hard that it can be reduced to powder, still retaining however its smell. In this state it occurs in commerce, filling small calabashes. It then contains 88 parts of resin, and 12 parts of benzoic acid.

The other variety is obtained by boiling the branches and bark of the tree in water. The balsam liquefies and falls to the bottom of the water. It has the consistency of honey, a brown colour, an agreeable smell, and a hot acrid taste. Specific gravity 1·15. When boiled with water for some time, the liquid separated by the filter reddens vegetable blues, and deposits crystals of benzoic acid on cooling. The water contains no other substance.* When distilled with water, it yields a very small quantity of reddish limpid oil. Hoffmann obtained only 1 part of oil from 16 of balsam.† Lichtenberg mixed 2 ounces of balsam with 8 of water, and distilled.

* Litchenberg, Gehlen's Jour. vi. 489. † Observ. Phys. Chim. Select. p. 71.

The first 2 ounces of water came over colourless, and had only a slight odour of the balsam. The next 3 were milky, smelt strongly of the balsam, and at the bottom of the receiver were some drops of colourless oil. The next 1½ ounce were similar, but contained more oil. Between 50 and 60 grains of benzoic acid had sublimed into the neck of the retort. By increasing the heat 3½ drachms of yellow oil came over, and a quantity of benzoic acid. A black shining coal remained in the retort.*

When this balsam is exposed to the heat of a water-bath, only a drop or two of water and a few drops of oil can be obtained.† When placed in a sand-bath, and exposed to a temperature gradually raised, nothing more comes over till the balsam is heated to 300°, when a portion of benzoic acid sublimes; and at 324°, drops of water and oil begin to come over. At 550° the balsam begins to boil, and some gas is disengaged. At 594° the oil (mixed with a little water) comes over pretty fast. At 617° it comes over still more rapidly. Lichtenberg, to whom we owe these experiments, kept 4 ounces of balsam at that temperature for two hours, and obtained 2 ounces of a yellowish oil, and a crystallized mass of benzoic acid, which, together with the water, weighed 6½ drachms. The gas obtained amounted to 58 ounce measures; of these 38 were carbonic acid. The rest burnt like olefiant gas. By increasing the heat, a brownish oil came over, and at last a black oil of the consistence of pitch, and 49 ounce measures of gas were extricated. Of these, six were carbonic acid; the residue burnt with a bluish white flame.‡

In absolute alcohol it dissolves in all proportions, but requires 5 times its weight of alcohol of 0·833, and the solution always remains muddy. When treated with ether, there is left a brown unctuous matter, while a volatile oil, benzoic acid, and a portion of resin are dissolved. Oil of turpentine when assisted by heat dissolves 0·51 of this balsam. The solution is brown. The undissolved portion is divided into two layers, one of which swims on the surface of the liquid, in the state of a syrupy matter, while a blackish-brown mass of a granular texture remains at the bottom of the vessel. Oil of almonds dissolves half the balsam without changing its colour or its smell. The undissolved portion is unctuous, and has a deep brown colour.

A saturated solution of carbonate of soda forms with this balsam a thick mass. When diluted with water and heated, a portion is dissolved. The solution, when saturated with sulphuric acid, deposits crystals of benzoic acid. One part of the balsam, treated with 1 part of potash dissolved in 4 parts of water, formed an opaque solution, which gradually separated into two portions: the uppermost, a clear oil with some grey flakes at its lower surface; the undermost, a dark brownish-red opaque solution. This last solution,

* Gehlen's Jour. vi. 485. † Lichtenberg, Gehlen's Jour. vi. 485.
‡ Ibid. p. 487.

when saturated with sulphuric acid, lets fall a resinous-like substance, dissolved by boiling, while benzoic acid crystallized.*

Nitric acid acts upon the balsam with energy, and gives it an orange-yellow colour when assisted by heat. When distilled with a sufficient quantity of this acid diluted, the liquid in the receiver smells of bitter almonds. When supersaturated with carbonate of potash, and mixed with a solution of iron, a precipitate falls, which, when treated with muriatic acid, leaves Prussian blue, and indicates the presence of prussic acid. During the distillation benzoic acid sublimes. The residue in the retort has a crystalline appearance, is light yellow, dissolves sparingly in boiling water, and precipitates on cooling in the state of a yellow powder.† Such was the result of Lichtenberg's trials. Mr Hatchett observed that the residue possessed the properties of artificial tannin.

When this balsam is treated with sulphuric acid, artificial tannin is also formed, and the residual charcoal amounts to no less than 0·64 of the original weight of the balsam.‡

According to the analysis of Stoltze, balsam of Peru is composed of

Volatile oil	69
Resin very soluble in alcohol .	20·7
Resin little soluble in alcohol .	2·4
Benzoic acid	6·4
Extractive matter . . .	0·6
Moisture	0·9
	100·0§

These constituents are distinguished by the following properties:—

1. *The oil* is much less volatile than the other volatile oils. Hence it can be separated from the balsam neither by distillation *per se*, nor mixed with water. To obtain it, Stoltze recommends the following method:—Mix 1 part of Peruvian balsam with 12 parts of pure and hot olive oil. The greatest part of the resin remains undissolved. Filter the oil and treat it with alcohol which will dissolve the volatile oil and the benzoic acid of the balsam. The benzoic acid is saturated with carbonate of potash, water is poured into the liquid, and the alcohol evaporated. The oil falls to the bottom of the aqueous solution of benzoate of potash. Wash it with water and dissolve it in 6 times its weight of alcohol of 0·871, which will leave undissolved a little elain of olive oil. When we evaporate the alcohol the oil remains in a state of purity.

The oil thus obtained is transparent, has a brownish-yellow colour, and the odour and taste of balsam of Peru. It does not evaporate spontaneously, and leaves greasy stains on paper. Its specific gravity is 1·084. It begins to boil at 257°, but the boiling point is continually rising during the whole time of the distillation, showing

* Lichtenberg, Gehlen's Jour. vi. 487. † Gehlen's Jour. vi. 491.
‡ Hatchett, Third Series of Experiments on Artificial Tannin, Phil. Trans, 1806.
§ Berl. Jahrbuch, xxv. 2, 24.

clearly that balsam of Peru contains a number of oils differing from each other in their volatility. There remains in the retort a bulky charcoal. The oil distilled over is light-yellow, very fluid, a little heavier than water, and has a rancid but not empyreumatic smell. It dissolves readily in alcohol of 0·860, and likewise in hot potash ley. It is insoluble in water, may be mixed in all proportions with absolute alcohol, but requires 4 times its weight of alcohol of 0·860 to dissolve it. It may be mixed with ether, oil of turpentine, and olive oil. Concentrated sulphuric acid dissolves it, and water precipitates it from this solution. Nitric acid acts upon it slowly, and seems to convert it into an acid similar to the fatty acids discovered by Chevreul. Concentrated acetic acid dissolves a small quantity of this oil, which is again precipitated by water. It seems to have the property of combining with potash, and of forming a kind of soap. In this, and several of its other properties, it approaches nearer to a fixed than a volatile oil.

2. The resin, very soluble in alcohol, precipitates when we mix the balsam with olive oil. Stoltze's method of procuring it is this: 1 part of the balsam is well agitated with 6 parts of alcohol of 0·860. The resin, little soluble in alcohol, remains undissolved. The alcoholic solution is evaporated to dryness, and the residuum mixed with 12 parts of hot olive oil, which dissolves the oil and the benzoic acid and leaves the resin. To make it pure, let it be treated with another similar dose of olive oil, and then dissolved in alcohol of 0·860. Should the solution contain benzoic acid, it is to be saturated as exactly as possible with carbonate of potash; hot water is poured into the liquid, and the alcohol is evaporated. The resin remains in a state of purity, and if it be melted in a moderate heat, the water which it may retain is driven off.

This resin has a deep brown colour, is destitute of taste and smell, and melts at a heat under 212°. It is insoluble in water and in ether, provided it be free from alcohol. It is insoluble also in oil of turpentine and olive oil. But it is very soluble in alcohol of less specific gravity than 0·871. The addition of water renders the liquid milky; but it is difficult to collect all the precipitated resin. Sulphuric, nitric, and acetic acids dissolve it with facility, but water throws it down from these solutions. It is very soluble in the caustic alkalies. By an excess of alkali the combination is separated from the liquid.

The alcoholic solution of this resin gives a green colour to the alcoholic solution of protochloride of iron, and throws down from the alcoholic solution of acetate of lead a brownish-grey precipitate, which is soluble in acetic acid. The same alcoholic solution of the resin renders muddy a solution of gelatine.

3. *Resin little soluble in alcohol.* It is blackish-brown, very brittle, destitute of taste and smell. When moderately heated it melts, giving out the smell of benzoin. It is soluble in boiling absolute alcohol; but the solution becomes muddy on cooling. It is insoluble in ether and in oils of turpentine and olives. Concen-

trated sulphuric acid dissolves it; nitric acid decomposes it; and acetic acid has no action, at least cold. By the assistance of heat it combines with the caustic alkalies, and acids separate it from these bodies unaltered. The alcoholic solution of this resin is precipitated by acetate of lead dissolved in alcohol. The precipitate is dissolved by acetic acid.

SECTION IV.—OF BALSAM OF TOLU.

This substance is obtained from the *tulifera balsamum*, a tree which grows in South America. The balsam flows from incisions made in the bark. It comes to Europe in small gourd shells. It is of a reddish-brown colour and considerable consistence; and when exposed to the air it becomes solid and brittle. Its smell is fragrant, and continues so even after the balsam has become thick by age. When distilled with water it yields very little volatile oil, but impregnates the water strongly with its taste and smell. A quantity of benzoic acid sublimes, if the distillation be continued.*

Mr Hatchett found it soluble in the alkalies like the rest of the balsams. When he dissolved it in the smallest possible quantity of lixivium of potash, it completely lost its own odour, and assumed a most fragrant smell, somewhat resembling that of the clove pink. "This smell," Mr Hatchett observes, "is not fugitive, for it is still retained by a solution which was prepared in June, and has remained in an open glass during four months."

When digested in sulphuric acid, a considerable quantity of pure benzoic acid sublimes. When the solution of it in this acid is evaporated to dryness, and the residue treated with alcohol, a portion of artificial tannin is obtained; the residual charcoal amounts to 0·54 of the original balsam.†

Mr Hatchett found that it dissolved in nitric acid with nearly the same phenomena as the resins; but it assumes the odour of bitter almonds, which leads him to suspect the formation of prussic acid. During the solution in nitric acid, a portion of benzoic acid sublimes. By repeated digestions it is converted into artificial tannin.‡

It dissolves completely in alcohol, ether, and the volatile oils. The fixed oils dissolve it incompletely.

SECTION V.—OF LIQUID STYRAX.

What is called liquid styrax in this country, and by the French, *baulme de copalme*, or *liquid amber*, is a juice which exudes from the *liquidambar styraciflua*, a tree which grows in Virginia, Mexico, and some other parts of America. But there can be no doubt that styrax was known to the Arabians before the discovery of America, and that it was brought to them from India. The oriental styrax

* Lewis, Neumann's Chem. p. 285.

† Hatchett, Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

‡ Ibid.

is the produce of the *liquidambar altingia*, a tree which is a native of Java.* Almost the whole of the styrax which occurs in commerce, has acquired from age nearly a solid consistence. But M. Bonastre was fortunate enough to obtain a fresh specimen which had been sent to Marseilles from South America. The following are its characters in that state:—

It has an oleaginous consistence, and is more or less transparent according to the temperature of the air. It has a strong smell, the same as that of liquid styrax of commerce. Its taste is acrid, sharp, and very aromatic. Its consistence depends upon the temperature. At 59° it is about equal to that of balsam of copaiva. At 32° it is very thick, and has lost its transparence. At 24° or 25° it is almost quite opaque, and seems to have a tendency to crystallize. This is owing to one of its immediate principles. Its specific gravity is less than that of water. Hence if dropt cautiously on water it spreads on the surface. But when let fall from a height it sinks to the bottom, and remains there: its levity not being sufficient to overcome the cohesion of the particles of water above it.

Alcohol at 91°½ dissolves about ⅔ds of it. The solution very slightly reddens litmus paper. The portion not dissolved is a white mass, consisting of a congeries of crystals. Ether dissolves it in all proportions. The solution is not quite transparent. This recent balsam of styrax was subjected to a chemical analysis by M. Bonastre, who obtained

1 Volatile oil . . .	7·00
2 Semiconcrete matter . .	11·1
3 Benzoic acid . . .	1·0
4 Crystalline matter soluble in water and alcohol	5·3
5 Yellow colouring matter .	2·05
6 Oleo-resin	49·0
7 Styracin	24·0
	99·45

The volatile oil was obtained by distilling the balsam along with water. It is liquid and transparent and colourless like water. It is lighter than water, but heavier than alcohol. Its smell is strong, and quite similar to that of liquid styrax. Its taste is acrid and burning, leaving a very disagreeable impression in the mouth. It communicates to water its taste and smell, though it dissolves only in minute quantity in that liquid. When distilled with precaution we obtain two products.

1. A transparent oil, having a strong aromatic taste and smell.

2. Towards the end a whitish, solid substance destitute of smell, and of the consistence of yellow wax. When dissolved in ether, it unites by evaporation into numerous small globules.

The volatile oil congeals at 32° It is then a semitransparent

* Jour. de Pharmacie, xviii. 711.

mass like camphor, but without any appearance of crystallization. Nitric acid converts it into a yellow resinous matter having the colour of gamboge; but no benzoic acid is formed. This volatile oil was analyzed by M. O. Henry, who found it composed of

Carbon	. .	89·25 or 10 atoms
Hydrogen	. .	10·46 or 7 atoms
		99·71*

If this analysis be correct, this volatile oil differs from oils of turpentine, lemon, juniper, pepper, and sabine, by containing an atom of hydrogen less united to the same number of atoms of carbon as in these oils.

The semiconcrete matter existed in the water distilled over with the volatile oil. It was obtained by agitating that liquid with ether. It was similar to the white matter obtained by distilling the volatile oil.

The water remaining in the retort being filtered had a yellow colour. Being concentrated it deposited a white crystalline matter in small globules. This constitutes the crystalline matter soluble in water and alcohol. From the account given of it by Bonastre, it seems to have some resemblance to *coumærin*.

The oleo-resin had an oily aspect, and was soluble in alcohol and ether. It was probably composed of an oil and a resin.

After the balsam had been boiled for 40 hours in water, it might be concluded that all the volatile oil had been separated, yet it still retained its soft consistence. It was boiled with lime and water, filtered, and decomposed by an acid. The whole was thrown on a filter, dried, and being introduced into a glass tube, was sublimed. Benzoic acid was by this means obtained.

When the balsam is treated with alcohol, about a fourth part remains undissolved, constituting a white crystalline mass. This is the substance which M. Bonastre has distinguished by the name of *styracin*.

The crystals consist of four-sided pyramids. They are insoluble in water, both cold and hot. Cold alcohol dissolves but a very small proportion of them. They dissolve in boiling alcohol, but are deposited in little spherical masses, consisting of congeries of crystals, as the liquid cools.

They have the consistence of yellow wax. Their smell has some resemblance to that of vanilla. They have little or no taste. They melt at a heat below that of boiling water. They have no action on vegetable blues. These crystals were analyzed by M. O. Henry, who obtained

Carbon	76·2728 or	11 atoms =	8·25	or per cent.	75·86
Hydrogen	5·5032 or	5 atoms =	0·625	— —	5·74
Oxygen	18·2240 or	2 atoms =	2·00	— —	18·40
	100·0000†		10·875		100·00

* Jour. de Pharmacie, xvii. 344. † Ibid. xvii. 350.

SECTION VI.—OF OPOBALSAMUM, OR BALM OF GILEAD—BALM OF MECCA.

This balsam is obtained from the *amyris Gileadensis*, and *amyris opobalsamum*, a tree which grows in Arabia, especially near Mecca. It is so much valued by the Turks, that it is seldom or never imported into Europe. It is said to be at first turbid and white, and of a strong aromatic smell, and bitter, acrid, astringent taste; but by keeping it becomes limpid and thin, and its colour changes first to green, then to yellow, and at last it assumes the colour of honey, and the consistence of turpentine.*

When rubbed between the hands, it is said to froth like soap. When poured into water, drop by drop, it spreads upon the surface of the liquid, and may be easily skimmed off by a feather. These two properties are considered as proofs of the goodness of opobalsamum.

It does not dissolve completely in alcohol even when assisted by heat. A transparent substance analogous to resin is left, having an agreeable smell. Alcohol of 0·815 dissolves, when assisted by heat, $\frac{2}{3}$ds of this substance, and leaves a flocky matter, thready when hot. The hot solution does not become muddy on cooling, and when left to spontaneous evaporation it deposits a few flocks of a transparent substance, similar to turpentine.

Trommsdorf examined opobalsamum, which came to him from Petersburg in leaden flasks. Its specific gravity was 0·950, at the temperature of 71°$\frac{1}{2}$. It had a peculiar odour, analogous to that of oil of lemons, or rosemary. When exposed to the air it was speedily converted into resin. He found its constituents to be

Volatile oil	30
Hard resin	64
Soft resin	4
Bitter colouring matter . .	0·4
	98·4

1. The *volatile oil*, obtained by distillation with water, is colourless, fluid, and has a very agreeable odour. Its taste is acrid. It dissolves in alcohol, ether, naphtha, and the fixed oils. Iodine is dissolved by it. Sulphuric acid dissolves it, assuming a dark-red colour, and water throws it down converted into a resin. Nitric acid converts it also into a resin, and communicates the odour of musk. It is soluble in concentrated acetic acid, but the caustic alkalies do not dissolve it. It is very easily converted into resin.

2. The *hard resin* is obtained by treating what remains after distilling off the oil with concentrated alcohol. The soft resin re-

* This is the account of Professor Alpinus, as quoted by Lewis, Neumann's Chem. p. 284.

mains while the hard is dissolved, and may be easily obtained by evaporating the solution. It is honey-yellow, transparent, brittle, and has a specific gravity of 1·333. At 111° it becomes as soft as turpentine, and at 196° it is in a state of complete fusion. Alcohol and ether dissolve it with the assistance of heat with great facility. The solution goes on cold, but not so well. Both the fixed and volatile oils dissolve it. Sulphuric acid dissolves it, assuming a deep orange-red colour, and water throws it down from this solution. Nitric acid of 1·25 scarcely acts on it, but concentrated acid decomposes it, while oxalic acid is formed, together with a yellow unctuous matter.

3. The *soft resin* is brown and very adhesive, yet it may, by degrees, be dried. It softens at 212°, and melts at 233°½. It is insoluble in alcohol, but soluble in fixed and volatile oils. Sulphuric acid does not dissolve it. Nitric acid causes it to swell, and renders it friable and yellow. Alkalies have no action on it.

Balm of Gilead has a high reputation among the Turks as an internal remedy.

M. Bonastre examined a specimen of opobalsamum that had been sent to Napoleon for the Empress Maria-Louise, and consequently genuine.*

By distilling it with water he obtained 10 per cent. of volatile oil. Its specific gravity was 0·876, it was quite transparent, had an agreeable turpentine smell, and a strong, sharp, aromatic taste. It dissolves in 12 times its weight of cold alcohol. Ether dissolves any quantity whatever. Acetic acid dissolves very little of it. Nitric acid, cold, has little action on it. Sulphuric acid gives it a red colour. It does not become solid though cooled down to 10°½. It does not combine with the alkalies.

The water had dissolved 4 per cent. of a brown, bitter extract, partly soluble in alcohol, and communicating to it a bitter taste.

The resin was dissolved in alcohol. The alcohol being driven off the resin remained viscid, and never acquired the solidity of resin from turpentine. It combines but imperfectly with the alkalies. It is but little acted on by nitric acid, even at a boiling heat, and no crystallizable substance is formed.

To the portion of resin insoluble in alcohol, Bonastre has given the name of *burserin*. It is solid, tasteless, and without smell. Its colour is greenish-white. It softens when heated, and cannot easily be reduced to powder. Very little soluble in boiling alcohol, and separates in white flocks as the solution cools. It dissolves readily in ether, but the solution does not yield crystals. It resembles very much the insoluble portion of the balsam from the *bursera gummifera*. This is the reason why Bonastre has called it *burserin*.

The following table shows the proportions of these constituents, obtained from 100 parts of opobalsamum by Bonastre:—

* Jour. de Pharmacie, xviii. 95.

Soluble viscid resin . . .	70
Burserin	12
Volatile oil	10
Bitter extract	4
Acid matter?	3
Impurities	1
	100

Canada balsam in commerce is sometimes substituted for opobalsamum. They are easily distinguished by the resins of each. The alcoholic solution of opobalsamum yields a viscid soft resin, that of Canada balsam a solid brittle resin.

SECTION VII.—OF CHINA VARNISH.

This is a natural balsam, employed in China as a varnish. According to Boureiro, it comes from a tree called *augia sinensis*, which grows in Cochinchina, China, and Siam.* It has the same consistence as turpentine, a brownish-yellow colour, an aromatic odour, and a strong astringent taste. It spreads on the surface of water, imbibing a little of that liquid, and becomes, at the same time, colourless and transparent. When the water is evaporated the balsam recovers its original appearance. It is composed of a *colourless oil*, having a strong smell, which may be distilled off along with water, of *benzoic acid*, and a *yellow resin*. It is soluble in alcohol, ether, and oil of turpentine. It is insoluble in caustic potash.†

This balsam constitutes the best varnish hitherto discovered. It mixes well with colours, and gives a very solid and beautiful covering.

DIVISION II.—SOLID RESINS.

These bodies are exceedingly numerous, having been extracted from a great variety of vegetable substances, and described more or less in detail by different chemists. But it would be an unprofitable waste of labour to collect all the facts on this prolific subject, scattered through an almost infinite number of books. It will be sufficient if those resins are described which occur in large quantities, and have been applied to purposes of utility.

SECTION I.—OF ROSIN, OR COLOFAN.

This is the name given to the resin which the different species of turpentines leave when they are deprived of their volatile oil by distillation. After this process it is melted with about $\frac{1}{5}$d of its weight of *galipot*,‡ placed upon a straw filter, and a little water is

* Jour. de Pharmacie, xv. 525.

† Macaire-Princep, Jour. de Pharmacie, xv. 525.

‡ Galipot is a mixture of resin from the *pinus abies* and *sylvestris*, which occurs in commerce in yellowish-grey pieces, varying much in size, soft within but hard on the surface. It is nothing else than common turpentine, deprived of a portion of its oil.

sprinkled on the melted mass. Thus prepared, it is common rosin, or resin. When it has a golden-yellow colour, it is called *Burgundy pitch.*

It has a deep brownish-yellow colour, is translucent, brittle, and has a specific gravity of 1·080. It softens at 156°, and melts at 275°.

It is composed chiefly of what Unverdorben called *pinic acid*, a substance which has been described in a preceeding part of this Chapter, while treating of *turpentine.* This resin is very easily altered into a *brown resin*, possessing more powerful acid characters, to which Unverdorben has given the name of *colophonic acid.* This change is produced by distilling pinic acid in a retort, till only $\frac{3}{4}$ths of it remain in the retort. Common rosin contains variable quantities of colophonic acid, according to the heat employed in preparing it. Sometimes it amounts to $\frac{1}{6}$th of the weight of the rosin. It is but little soluble in alcohol of the specific gravity 0·879; but the solubility is increased when it is mixed with pinic acid.

The salts which it forms with bases have been described by Unverdorben in detail. But they are so similar in their characters to the pinates, that any description would be little else than a repetition of what has been already stated, when giving an account of turpentine.*

Blanchet and Sell have shown that rosin is a compound of 1 atom oil of turpentine, and 1 atom oxygen; or that it consists of $C^{10} H^8 O$.† H. Rose has ascertained that the resin from copaiva has exactly the same constitution.‡ Rose analyzed the crystallized resin of colophan, and obtained

Carbon	79·15	or 10 atoms	= 7·5	or per cent.	78·94
Hydrogen	9·93	or 8 atoms	= 1	— —	10·53
Oxygen	10·92	or 1 atom	= 1	— —	10·53
	100·00		9·5		100·00

He analyzed the colophonates of silver and lead, and found the composition the same as those into which the crystallized resin of copaiva enters. Hence the atomic weight of this resin is 38, and its composition 4 ($C^{10} H^8 O$), or 2 ($C^{10} H^8 O$).

The uncrystallizable resin of colophan, called *silvic acid* by Unverdorben, has been found by Rose to have the same atomic weight as the crystallizable resin.§

We are indebted to M. Fremy for an important set of experiments on the products of rosin, when distilled *per se*, or along with lime.‖ To free the rosin as completely as possible from oil of turpentine, it was heated in a retort, a good deal of water and oil of turpentine at first escaped, and the heat was continued till these substances ceased to come over.

When the heat is now increased, there passes over a very heavy,

* See Poggendorf's Annalen, vii. 311. † Ibid. xxix. 133.
‡ Ibid. xxxiii. 35. § Ibid. p. 45. ‖ Ann. der Pharm. xv. 282.

light-coloured oil, almost destitute of taste and smell. It is scarcely soluble in alcohol, not at all in water; but exceedingly soluble in ether. It requires a heat above 482° to cause it to boil. But it may be distilled over unaltered. Caustic potash seems to have no action on it. Nitric acid decomposes it, and converts it into a yellowish resinous-looking matter, while nitrous acid is disengaged. Litharge decomposes it in the same way, while the oxide is reduced.

This oil burns like the fixed oils, with which it has many things in common.

Its constituents, as determined by Fremy, are

Carbon	84·6 or 20 atoms	= 15	or per cent.		83·91
Hydrogen	10·7 or 15 atoms	= 1·875	—	—	10·50
Oxygen	4·7 or 1 atom	= 1	—	—	5·59
	100·0	17·875			100

Now 2 atoms rosin are C^{20} H^{16} O^2.

If from this we abstract an atom of water H O, we have an atom of the oil.

Fremy has given to this oil the name of *resinein*.

When 1 part of purified rosin is intimately mixed with 8 times its weight of slacked lime, and cautiously heated in a retort, an oil comes over having a very ethereal smell, and always swimming in a little water. This oil is to be distilled a second time in an oil-bath of the temperature 320°. By this distillation the product is divided into two portions. One portion, which remains in the retort and does not distil over at 320°, is a mixture of *resinein* and *tar*. What comes over consists also of two, or (if the resin has not been quite freed from oil of turpentine) of three distinct substances.

The first of these substances is very volatile, the second is less so, and the third (when it is present) is oil of turpentine. The oil of turpentine may be separated by digesting the product in alcohol; which dissolves the two first substances readily, but very little of the oil of turpentine.

The two substances may be separated from each other by rectifying at a low temperature. There passes over a white very liquid substance, having a burning taste, insoluble in water but soluble in alcohol, and still more so in ether. It burns like alcohol, and boils at 172°½.

This substance, to which M. Fremy has given the name of *resinone*, was analyzed by him. He found the constituents to be

Carbon	77·81 or 10 atoms	= 7·5	or per cent.		77·93
Hydrogen	11·76 or 9 atoms	= 1·125	—	—	11·68
Oxygen	10·43 or 1 atom	= 1	—	—	10·39
	100	9·625			100

It therefore differs from oil of turpentine, by containing an additional atom of water.

When, after the separation of the *resinone*, the distillation is continued, we obtain a less volatile oil, which has a less burning taste,

boils at 298°½, and is somewhat less soluble in alcohol than resinone. According to the analysis of Fremy it is composed of

Carbon	83·91 or 23 atoms	=	17·25	or per cent.	84·14
Hydrogen	11·10 or 18 atoms	=	2·85	— —	10·98
Oxygen	4·99 or 1 atom	=	1·5	— —	4·88
	100		20		100

To this substance Fremy has given the name of *resineon*.

SECTION II.—OF MASTICH.

This resin is obtained from the *pistacea lentiscus*, a tree which grows in the Levant, particularly in the island of Chios. When transverse incisions are made into this tree, a fluid exudes, which soon concretes into yellowish semitransparent brittle grains.* In this state it is sold under the name of mastich. It softens when kept in the mouth, but imparts very little taste. This has induced surgeons to employ it to fill up the cavities of carious teeth, which it does tolerably well. When heated, it melts and exhales a fragrant odour. Its taste is slight, but not unpleasant. In Turkey great quantities of it are said still to be chewed for sweetening the breath, and strengthening the gums. It is to this use of the resin as a masticatory that it is supposed to owe its name.† Mastich does not dissolve completely in alcohol; a soft elastic substance separates during the solution. This substance, in Neumann's experiments, amounted to about $\frac{1}{12}$th of the mastich;‡ but in those made more lately by Mr Matthews, it was nearly a fifth.§ The nature of this insoluble portion was first examined by Kind,‖ who found it possessed of all the properties of caoutchouc. These experiments have been repeated by Mr Matthews with a similar result.§ Mr Brande, however, has observed, that when this insoluble substance is dried it becomes brittle, in which respect it differs from caoutchouc. He has observed also, that by passing a current of chlorine gas through the alcoholic solution of mastich, a tough elastic substance is thrown down, precisely similar to the original insoluble portion.¶ When mastich is distilled either with water or alcohol, nothing considerable comes over with these liquids; but Hoffmann ascertained, that if the resin be first mixed in a mortar with its own weight of carbonate of potash, and afterwards distilled with alcohol, the liquid comes over both with the smell and taste of mastich.** The portion insoluble in alcohol, possesses very nearly the characters of *copal*. It is soluble in absolute alcohol, ether, and oil of turpentine. These liquids dissolve mastich likewise, without leaving any residue. If the portion at first insoluble in aqueous alcohol, be pounded and left long in a warm place, it becomes at last soluble in aqueous alcohol. The resin of mastich has been shown by Unverdorben, to possess acid properties similar to that of common rosin, which he has called pinic

* See Neumann's Chem. p. 297. † Ibid. p. 298. ‡ Ibid.
§ Nicholson's Jour. x. 247. ‖ Crell's Annals, 1794, ii. 185.
¶ Phil. Mag. xxv. 111. ** Hoffmann, Observ. Phys. Chim. Select. p. 68.

acid. And from his experiments it would seem to saturate very nearly the same weight of basis with that resin.*

In this country mastich is used sometimes for stuffing decayed teeth. I am not aware that it constitutes an ingredient in any of the plasters employed by British practitioners; though it does so to a considerable extent on the continent of Europe.

SECTION III.—OF SANDARACH.

This resin is obtained chiefly from the *thuya articulata*, which grows in Barbary.† It exudes spontaneously, and is usually in the state of small round tears of a brown colour, and semitransparent, not unlike mastich, but rather more transparent and brittle. When chewed it does not soften as mastich does, but crumbles to powder. Mr Matthews found it almost completely soluble in eight times its weight of alcohol. The residue was extraneous matter.‡ It does not dissolve in tallow or oil, as common resin does.§ Mr Hatchett found it soluble in alkalies and acids with the same phenomena as common resin. It melts at 308°, and froths, giving out an agreeable smell.

Unverdorben has analyzed sandarach, and has found it composed of three resins. If we dissolve it in absolute alcohol, and add a solution of hydrate of potash to the liquid, a resinate of potash precipitates in the form of a viscid mass. When the liquid is left at rest in a cool place, it gradually deposits an additional quantity of this resinate. It retains in solution the compound of potash with the two other resins, which may be thrown down by pouring into the liquid very dilute muriatic acid. The mixture of these two resins thus precipitated is washed and dried, and then boiled in alcohol of the specific gravity 0·879, which dissolves the one and leaves the other. The resin thus dissolved by the weak alcohol may be called *resin a*, that left undissolved *resin b*, and that precipitated at first by the potash *resin c*.

1. The *resin a* is very analogous to the *pinic acid* from turpentine. It is soluble in alcohol, ether, and oil of turpentine. Naphtha only dissolves it partially; but the portion undissolved possesses the same characters as the portion dissolved. It is easily soluble both in ammonia and in caustic potash. By an excess of the latter it is thrown down in the state of viscid resinate of potash. Most salts with an alkaline base produce the same effect. The resinate of potash when dried is brown and brittle; soluble in alcohol and water, but insoluble in ether. The alkaline carbonates when boiled with this resin are decomposed. When the resinate of ammonia is boiled, the ammonia is disengaged, and the pure resin precipitates.

This resin, by double decomposition with the salts of the earths and metallic oxides, forms compounds which are insoluble in alcohol and ether. The resinate of copper, formed by *resin a* of sandarach, is

* Poggendorf's Annalen, vii. 311. † Thenard, Traité de Chimie, iii. 225.
‡ Nicholson's Jour. x. 246. § Ibid.

insoluble in ether, which distinguishes it from the pinate of copper, formed by the pinic acid from turpentine.

2. *Resin b* remains in the state of a viscid mass, when *resin a* has been separated from it. It retains a little alcohol, from which it may be freed by boiling it in water. It is a yellow resin, soluble in ether and absolute alcohol; but insoluble in oil of turpentine and naphtha. The volatile oil from *carum carvi* dissolves it readily. It combines also with the bases, and forms salts. Its resinate of potash is very soluble in water, but it is precipitated from its solution by an excess of potash, and by the salts having potash for a base. This resinate is oleaginous at the temperature of 212°; but at the usual temperature of the air it is hard and brittle, and may easily be crumbled to powder between the fingers. When solid it dissolves slowly in cold, rapidly in boiling water. It is also soluble in alcohol, but not in ether. When its aqueous solution is decomposed by an acid, the resin precipitates in a gelatinous state. By boiling it contracts, and becomes light and porous, but does not assume the aspect of a resin.

The resinate of ammonia is easily formed, and is not decomposed though raised to the boiling point. The resinates of the earths and metallic oxides are powders, insoluble in water, alcohol, and ether. When chloride of gold is decomposed by resinate of potash, we obtain a red coloured resinate of gold.

3. *Resin c* is obtained by the following process:—Dissolve in boiling alcohol of 0·879 the resinate of potash precipitated from the alcoholic solution of sandarach. Precipitate this solution, while still boiling hot, by muriatic acid, and wash the white powder precipitated. It is a resin containing water, which may be driven off by heat. This resin does not fuse but at a pretty high temperature. It assumes a shade of brown, but does not undergo decomposition. Alcohol of 0·879 does not act on it; but it dissolves in all proportions when digested in alcohol of 0·822, or stronger, and also in ether. Oils of turpentine, carvi, and naphtha have no action on it. This resin, while moist, dissolves readily in potash, but after being dried, it dissolves only slowly. The resinate of potash is precipitated in the state of a jelly, from its aqueous solution, both by an excess of alkali, and by the salts with an alkaline base. It preserves its gelatinous state even when boiled, and dissolves readily in water.

After being dried, it is a light-brown resin, which loses its water without any other change when heated to 536°. It becomes viscous in alcohol, but does not dissolve. When placed in contact with it, cold, it combines with a certain quantity of that liquid, and is divided into scales. In boiling water it swells like gum tragacanth, but very little of it is dissolved. If we now add a little alcohol, it becomes as soluble as at first.

While this resin retains its water, it combines with ammonia, without altering its form, and without dissolving. This resinate of ammonia is soluble in absolute alcohol, when assisted by heat, but on cooling it falls down again in flocks. We may boil this resin-

ate in water without depriving it of its ammonia; but it is gradually volatilized when the resinate is exposed to the air.

The earthy and metallic resinates of this resin are insoluble in water, alcohol, and ether.

SECTION IV.—OF ELEMI.

This resin is obtained by incisions from the *amyris elemifera*, a shrub which is a native of South America, and from the *amyris ceylonica*, or *balsamodendron zeylanicum*, which, as the specific name implies, is a native of Ceylon. Incisions are made in the bark during dry weather, and the resinous juice which exudes is left to harden in the sun. It comes to this country in long roundish cakes wrapped in flag leaves. It is of a pale yellow colour, semitransparent; at first softish, but it hardens by keeping. Its smell is at first strong and fragrant, but it gradually diminishes. Neumann found that alcohol dissolved $\frac{15}{16}$ths of this substance; the remainder consisted chiefly of impurities, and was partly taken up by water. Both water and alcohol, when distilled with it, come over strongly impregnated with its flavour. Along with the water there comes over a fragrant volatile oil, which amounts to about $\frac{1}{16}$th of the resin employed.*

When heated, or rubbed with a pointed instrument in the dark, it becomes luminous. Sulphuric acid converts it into tannin, and nitric acid into a bitter tasted substance, which throws down the metallic salts, without altering a solution of gelatin. According to an analysis of Bonastre, elemi is composed of

Volatile oil	12·5
Transparent resin, soluble in cold alcohol .	60·0
Milk-white do., soluble in boiling alcohol .	24·0
Bitter substance	2·0
Impurity	1·5
	100†

The alcoholic solution of the transparent resin reddens vegetable blues.

The milk-white resin dissolves in boiling alcohol, but when the solution is cooled slowly, it precipitates in crystals. It is colourless, in powder, and insoluble in the alkalies.

H. Rose analyzed this resin, and found its constituents—

Carbon	83·05 or 10 atoms	= 7·5	or per cent.	83·33
Hydrogen	11·28 or 8 atoms	= 1	— —	11·11
Oxygen	5·67 or ½ atom	= 0·5	— —	5·55
	100·00‡	9·0		100·00

It has, therefore, the same constituents with rosin, but contains only half as much oxygen. It is not endowed with acid properties.

This resin is sometimes used in varnishes.

* Neumann's Chem. p. 296. † Schweigger's Jour. xxxvi. 366.
‡ Poggendorf's Annalen, xxxiii. 49.

SECTION V.—OF TACAMAHAC.

There are two species of resin distinguished by this name. One comes from the Isle of Bourbon and Madagascar, and is extracted from the *callophyllum inophyllum*. It is yellow, translucent, adhesive, has an agreeable smell, and an acrid taste. It occurs but rarely in commerce.

The other species is obtained from the *fagara octandra*, and likewise, it is supposed, from the *populus balsamifera*. It comes from America in large oblong masses wrapt in flag leaves. It is of a light-brown colour, very brittle, and easily melted when heated. When pure it has an aromatic smell between that of lavender and musk. When distilled along with water or alcohol, nothing comes over with these liquids.* It is but partially soluble in alcohol. Ether, on the other hand, and the fixed oils, dissolve it completely. The Bourbon species is completely soluble in alcohol. The acids act upon it nearly as upon the resins in general. The tannin formed from it by nitric acid precipitates metallic solutions; but not gelatin.

SECTION VI.—OF LABDANUM, OR LADANUM.

This resin is obtained from the *cystus creticus*, a shrub which grows in Syria and the Grecian Islands. The surface of this shrub is covered with a viscid juice, which, when concreted, forms ladanum. It is collected while moist by drawing over it a kind of rake with thongs fixed to it. From these thongs it is afterwards scraped with a knife. It is always mixed with dust and sand, sometimes in great abundance. The best is in dark-coloured masses, almost black, and very soft, having a fragrant odour and a bitterish taste. The impurities, even in the best kinds, amount to about $\frac{1}{4}$th. Water dissolves rather more than $\frac{1}{12}$th of the pure portion, and the matter taken up is said to possess gummy properties. When distilled with water, a small quantity of volatile oil rises. Alcohol likewise comes over impregnated with the taste and smell of labdanum.†

SECTION VII.—OF BOTANY BAY RESIN.

This resin is said to be the produce of the *acarois resinifera*, a tree which grows abundantly in New Holland, especially near Botany Bay. Specimens of it were brought to London about the year 1799, where it was tried as a medicine. Some account was given of it in Governor Philips' *Voyage*,‡ and in White's *Journal of a Voyage to New South Wales*;§ but it is to Professor Lichtenstein that we are indebted for an account of its chemical properties. He obtained specimens from London, and published the result of his experiments in *Crell's Journal*.‖

The resin exudes spontaneously from the trunk of the singular tree which yields it, especially if the bark be wounded. It is at first fluid, but becomes gradually solid when dried in the sun. Accord-

* Neumann's Chem. p. 295. † Ibid. p. 295.
‡ Duncan's New Dispensary, p. 60. § Appendix, p. 245. ‖ 1799, ii. 242.

ing to Governor Philips, it is collected usually in the soil which surrounds the tree, having doubtless run down spontaneously to the ground. It consists of pieces of various sizes of a yellow colour, unless when covered with a greenish-grey crust. It is firm, yet brittle; and when pounded, does not stick to the mortar nor cake. In the mouth it is easily reduced to powder without sticking to the teeth. It communicates merely a slight sweetish astringent taste. When moderately heated, it melts; on hot coals it burns to a coal, emitting a white smoke, which has a fragrant odour somewhat like storax. When thrown into the fire, it increases the flame like pitch. It communicates to water the flavour of storax, but is insoluble in that liquid. When digested in alcohol, $\frac{2}{3}$ds dissolve; the remaining third consists of 1 part of extractive matter, soluble in water, and having an astringent taste; and 2 parts of woody fibre and other impurities, perfectly tasteless and insoluble. The solution has a brown colour, and exhibits the appearance and the smell of a solution of benzoin. Water throws it down unaltered. When distilled, the products were water, and empyreumatic oil, and charcoal; but it gives no traces of any acid, alkali, or salt, not even when distilled with water.

Twelve parts were boiled in a solution of pure soda in water. 2 parts of the resin were dissolved; the remaining 10 parts were floating on the solution, cohering together in clots. No crystals were obtained by evaporating part of the solution; and when sulphuric acid was dropped into another portion, resin separated unaltered. When mixed with twice its weight of nitric acid, the resin swims unaltered on the surface; but when heat is applied, a considerable effervescence takes place. The digestion was continued till the effervescence stopped, and the resin swam on the surface of the liquid collected together in clots. It was then separated by filtration. It had lost $\frac{1}{12}$th of its weight. The resin thus treated had acquired a bitterish taste, was not so easily melted as before, and alcohol was capable of dissolving only one-half of it. The solution was brown, tasted like bitter almonds; and when mixed with water, let fall a yellow resinous precipitate of a very bitter taste. The insoluble portion mixed with water, but formed a turbid liquid, which passed through the filter. The nitric acid solution separated from the resin by filtration was transparent; its colour was yellow; its taste bitter; and it tinged substances dipped into it of a yellow colour. By evaporation it yielded oxalic acid, and deposited a yellow earthy-like powder. This last substance was insoluble in water, and scarcely soluble in alcohol. Its taste was exquisitely bitter, like quassia. It mixed with the saliva, and readily stained the skin and paper yellow. The residuum continued bitter and yellow; but yielded no precipitate with potash and nitrate of lime.*

SECTION VIII.—OF BLACK POPLAR RESIN.

In the year 1770, the black poplar was pointed out, in a German

* Lichtenstein, Crell's Jour. 1799, ii. 242.

periodical work, as a tree from which abundance of wax could be obtained. It was even said that a manufactory of candles, from the wax of this tree, had been established in Italy. This account having been revived in 1804, Schræder was induced to make a set of experiments on the subject. He found, that when the buds of this tree are boiled in water and properly pressed, they yield about $\frac{1}{8}$th of their weight of a yellowish-white substance, which possesses the properties of a resin, and resembles, according to him, the yellow resin of Botany Bay. When digested in water, a coloured solution is obtained, which reddens litmus paper, which becomes muddy by cooling, and which, when evaporated, deposits small crystals.*

SECTION IX.—OF GUAIACUM.

This resin is obtained from the *guaiacum officinale*, a tree which is a native of the West Indies, and yields a very hard heavy wood. The resin exudes spontaneously, and is also driven out artificially by heating one end of the wood in billets previously bored longitudinally; the melted resin runs out at the extremity farthest from the fire. This substance has been used in medicine for a considerable time, having been originally recommended in the venereal disease. Nothing is known concerning its original introduction into Europe.

Guaiacum is a solid resin. Its colour differs considerably, being partly brownish, partly reddish, and partly greenish; and it always becomes green when left exposed to the light in the open air.† It has a certain degree of transparency, and breaks with a vitreous fracture. When pounded it emits a pleasant balsamic smell, but has scarcely any taste, although when swallowed it excites a burning sensation in the throat. When heated it melts, and diffuses at the same time a pretty strong fragrant odour. Its specific gravity is 1·2289.‡

When guaiacum is digested in water a portion of it is dissolved, the water acquiring a greenish-brown colour and a sweetish taste. The liquid, when evaporated, leaves a brown substance, which possesses the properties of *extractive;* being soluble in hot water and alcohol, but scarcely in sulphuric ether, and forming precipitates with muriates of alumina, tin, and silver. This extractive amounts to about nine parts in the hundred of guaiacum.§

Alcohol dissolves guaiacum with facility, and forms a deep brown-coloured solution. Water renders this solution milky by separating the resin. Muriatic acid throws down the guaiacum of an ash-grey, and sulphuric acid of a pale-green colour. Acetic acid and the alkalies occasion no precipitate. Liquid chlorine throws it down of a fine pale-blue, which does not change when dried. Diluted nitric acid occasions no change at first; but after some hours the liquid becomes green, then blue, and at last brown, and at that period a brown-coloured precipitate falls down. If water be mixed

* Schræder, Gehlen's Jour. vi. 598. † Wollaston, Nicholson's Jour. viii. 294.
‡ Brande, Phil. Mag. xxv. 105. § Ibid.

with the liquid when it has assumed a green or a blue colour, green and blue precipitates may be respectively obtained.*

Sulphuric ether does not act so powerfully on guaiacum as alcohol. The solution obtained by means of it exhibits the same properties when treated with reagents as that in alcohol.†

The alkaline solutions, both pure and in the state of carbonates, dissolve guaiacum with facility. 2 ounces of a saturated solution of potash dissolved about 65 grains of guaiacum; the same quantity of ammonia only 25 grains; or guaiacum dissolves in about 15 parts of potash and 38 parts of ammonia. Nitric acid threw down from these solutions a brown precipitate, similar to what is obtained when the alcoholic solution is mixed with the same acid. Muriatic acid and diluted sulphuric acid throw down a flesh-coloured curdy precipitate, which in its properties approaches the nature of extractive.‡

Most of the acids act upon guaiacum with considerable energy.

Sulphuric acid dissolves it, and forms a deep-red liquid, which deposits while fresh a lilac-coloured precipitate when mixed with water. When heat is applied the guaiacum is charred.

Nitric acid dissolves guaiacum completely without the assistance of heat, and with a strong effervescence. When the solution is evaporated, it yields a very large quantity of oxalic acid.§ No artificial tannin appears to be formed, but rather a substance possessing the properties of extractive. Diluted nitric acid converts guaiacum into a brown substance, similar to the precipitate obtained by nitric acid from the alcoholic solution of guaiacum. This brown matter possesses the properties of a resin.‖

Muriatic acid acts but slightly, as the guaiacum soon melts into a blackish mass, which is not acted upon.¶

Guaiacum is rendered blue by various animal and vegetable substances. It becomes blue, according to Tadei, when rubbed in the state of powder with gluten of wheat, or with the farina which it contains. Planche observed that when transverse slices of the fresh roots of certain plants are cut, and some drops of tincture of guaiacum let fall on them, they become blue, even though the air have no access to them. This phenomenon was produced on the roots of the following plants:—

Cochlearia armoracia	Daucus carota
Symphitum officinale	Glycyrrhiza glabra
Leontodon taraxacum	Brassica napus
Cichorium intibus	Arctium lappa
Eryngium campestre	Colchicum autumnale
Iris germanica	Saponaria officinalis
Nymphæa alba	Fumaria officinalis
Solanum tuberosum	Rumex acetosa
Inula helenium	Scorzinera hispanica

* Brande, Phil. Mag. xxv. 106. † Ibid. p. 106. ‡ Ibid. p. 109.

§ Hatchett, Second Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

‖ Brande, Phil. Mag. xxv. 107. ¶ Ibid.

Borago officinalis Allium ceva.
Angelica archangelica

These roots lose the property of becoming blue, when heated to 212°, or when dried.

The roots of the following plants do not become blue :—

Polypodium filex mas
Rumex acutus
Fragaria vesca.

Gum arabic dissolved in cold water does not produce the blue colour, except when in contact with air ; and it does not produce it at all if the gum has been dissolved in boiling water. Gum tragacanth, whether dissolved in hot or cold water, produces no effect. Tincture of guaiacum loses the property of becoming blue, when kept in badly-corked phials. Milk also strikes a blue with tincture of guaiacum, but when boiled it loses that property, and does not recover it, though cooled and left exposed to the action of the air.

Unverdorben has analyzed guaiacum, and found it composed of two resins, one of which constitutes but a small portion of the mixture. They are separated by digesting powdered guaiacum in liquid ammonia, which dissolves the one and leaves the other.

1. The *resin* which is soluble in ammonia constitutes but a small portion of the guaiacum. It dissolves in all proportions in ammonia. It is equally soluble in alcohol, and precipitates the alcoholic solution of acetate of copper.

2. The *resin* insoluble in ammonia absorbs a considerable portion of that alkali during the digestion, and becomes viscid. But the compound formed requires more than 6000 times its weight of water to dissolve it. The resin may be separated by an acid from the ammonia. It possesses the characters of guaiacum already described, as it constitutes the principal part of that substance. It dissolves in alcohol, but the solution is not precipitated by acetate of copper. It is very soluble in potash, and when boiled with the carbonate of that alkali, separates the carbonic acid from it.

If we add, drop by drop, a solution of the resinate of potash into a solution of the protochloride of iron or mercury, a blue precipitate falls, consisting of a blue resin mixed with the respective chloride. Alcohol dissolves the blue resin, and leaves the resinate. When the alcohol is driven off by evaporation, there remains a deep blue resin, which on fusion becomes brown, and quite similar to guaiacum. The sulphuric and muriatic acids destroy the blue colour without dissolving the resin. Potash dissolves it and destroys the blue colour. When this oxide is disoxygenized it becomes brown ; and it would appear that the addition of oxygen gives it a similar colour.

If we evaporate to dryness an alcoholic solution of the resin of guaiacum, and melt in a low heat the resin thus obtained, to drive off the whole of the alcohol, and then dissolve it in caustic potash, so as to saturate the alkali with the resin, and then drop very slowly this alkaline solution into a dilute solution of protochloride of gold,

taking care not to precipitate all the gold, we obtain a blue-coloured precipitate, which becomes pulverulent when boiled, and assumes a violet colour when treated with nitric acid. This precipitate is a compound of peroxide of gold and the resin. Potash dissolves it, assuming a purple-red colour. It is insoluble in alcohol and ether, and is precipitated by alcohol from its aqueous solution.

The resinate of potash may be used to obtain, by double decomposition, other resinates from the earthy and metallic salts.

Guaiacum is a good deal employed in medicine. When given to the extent of half a scruple, it frequently acts as a sudorific. It is often adulterated with common rosin. To discover this fraud, we have only to dissolve the guaiacum in caustic potash. If the guaiacum be pure the solution is limpid, but muddy if rosin be present, as long as there is an excess of alkali; because this excess precipitates the pinate and silvate of potash from the solution.

SECTION X.—OF STORAX.

This is the most fragrant of all the resins, and is obtained from the *styrax officinalis*, a tree which grows in the Levant, and it is said also in Italy. Sometimes it is in the state of red tears; and this is said to be the state in which it is obtained from the tree. But common storax is in large cakes; brittle, but soft to the touch, and of a reddish-brown colour. This is more fragrant than the other sort, though it contains a considerable mixture of saw-dust. It dissolves in alcohol. When distilled with alcohol or with water, scarcely any oil is obtained. When distilled by the naked fire, it seems, from the experiments of Neumann, to yield the same products as benzoin.*

SECTION XI.—OF DRAGON'S BLOOD.

This is a brittle substance of a dark-red colour, which comes from the East Indies. There are two sorts of it; one in small oval drops or tears of a fine deep red, which becomes crimson when the tears are reduced to powder; the other is in larger masses, some of which are pale red, and others dark. It is probably obtained from different kinds of trees; the *calamus draco* is said to furnish most of what comes from India. The *dracæna draco*, and the *pterocarpus draco* are also said to furnish it.

Dragon's blood is brittle and tasteless, and has no sensible smell. Water does not act upon it, but alcohol dissolves the greatest part, leaving a whitish-red substance, partially acted upon by water. The solution has a fine deep-red colour, which stains marble, and the stain penetrates the deeper the hotter the marble is. It dissolves likewise in oils, and gives them a deep-red colour also. When heated it melts, catches flame, and emits an acid fume similar to that of benzoic acid.† When digested with lime, a portion of it becomes soluble in water, and it acquires a balsamic odour. On

* Neumann's Chemistry, p. 290.

† Lewis, Neumann's Chem. p. 299.

adding muriatic acid to the solution, a red resinous substance is precipitated, and slight traces of benzoic acid only become perceptible.* Nitric acid acts upon it with energy, changes it to a deep yellow, a portion of benzoic acid is sublimed, and a brown mass remains, soluble in water and possessing the properties of artificial tannin.† When treated with sulphuric acid no perceptible portion of benzoic acid sublimes; but it is converted partly into artificial tannin, while a quantity of charcoal is evolved, amounting to 0·48 of the original dragon's blood employed.‡

Herberger has analyzed dragon's blood, and has found it composed of

Fixed oil	2·0
Red resin§	90·7
Benzoic acid	3·0
Oxalate of lime . . .	1·6
Phosphate of lime . . .	3·7
	101·0‖

According to Melandri, when dragon's blood is acidulated with sulphuric acid, that acid assumes a yellow colour, and leaves undissolved a substance which he calls *dracin*, and which he considers as a vegetable alkaloid.

Dracin has a fine red colour, and is very easily melted. It may be kneaded between the fingers and drawn out into threads. It melts at 131°. After congealing it has a crimson-red colour, and when triturated, gives a cinnabar-red powder. It dissolves readily in alcohol; and the solution, which has a fine red colour, becomes yellow when an acid is added. If we add sulphuric acid to the alcoholic solution, and then precipitate by water, we obtain a yellow precipitate, composed of the dracin and the acid; and when freed by washing from the alcohol and the uncombined acid, dissolves in a great quantity of water, and gives a yellow solution. The smallest addition of alkali added to this solution gives it a red colour by saturating the acid.

It does not appear to me that Melandri has established the alkaline properties of this substance. It combines with potash, and seems to possess properties analogous to those of the acid resins. This is also the opinion of Herberger, deduced from experiments.

Dragon's blood is occasionally employed by apothecaries to colour tinctures. It is used also to give a red colour to varnishes.

SECTION XII.—OF DAMMARA.

The resin distinguished by this name has been recently brought

* Hatchett, Second Series of Experiments on Artificial Tannin, Phil. Trans. 1806. † Hatchett, ibid.

‡ Hatchett, Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

§ He distinguishes this resin by the name of *draconin*. He considers it as a weak acid.

‖ Jour. de Pharmacie, xvii. 225.

from the East Indies. It is supposed to be the production of the *pinus dammara*, or *dammara alba*. It has been examined by Lucanus and Brandes.

It is transparent, and sometimes colourless, sometimes slightly yellow, destitute of taste and smell. Its specific gravity varies from 1·097 to 1·123. It is easily melted, and gives out no smell when fused. It is partially soluble in alcohol, and almost completely in ether. Oil of turpentine and the fixed oils dissolve it altogether. Concentrated sulphuric acid dissolves it, and assumes a red colour. Water throws it down from this solution with its properties a little altered. Nitric acid may be distilled off it without converting it into artificial tannin. By this process $\frac{1}{5}$th of the dammara becomes soluble in water, while the remaining $\frac{4}{5}$ths dissolve partially in alcohol, and completely in ether.

Potash and ammonia, when boiled with this resin, combine with it. The resinate of potash is but little soluble in water, since, when treated with boiling water, $\frac{2}{3}$ds of it remain undissolved. When we dissolve dammara in oil of turpentine, and boil it with a solution of potash till all the oil of turpentine is driven off, we obtain a resinate of potash entirely soluble in water and in alcohol.

Brandes analyzed dammara, and found it composed of

A resin soluble in alcohol . .	83·1
A resin insoluble in alcohol .	16·8
	99·9

With a trace of gum and succinic acid. Let us call the resin soluble in alcohol, *resin a*, and the other *resin b*.

1. *Resin a*, precipitated by water from its alcoholic solution, retains obstinately a portion of the alcohol. In that state it is soft, dark-brown, and transparent. It contains, at the same time, a little volatile oil, which gives it a smell similar to that of copaiva. The alcohol may be separated by boiling it in water, or by melting it in a gentle heat. It is then hard. It dissolves in less than its weight of absolute alcohol. In alcohol of 0·855 it does not dissolve, except by the assistance of heat. It dissolves in ether, oils of turpentine, and lavender, and in the fixed oils. Sulphuric acid and muriatic acid give it a red colour, and redden also its solutions; but the resin is altered in its properties. Dilute phosphoric acid dissolves a little of it by the assistance of a boiling heat. Nitric acid darkens its colour and decomposes it.

2. *Resin b*, called also *dammarin*, is very little soluble in cold absolute alcohol. When dammara is digested in boiling absolute alcohol, and the solution allowed to cool, the *resin b* is deposited. It is a snow-white powder, light and bulky. It is fusible, and burns with flame when held to a candle. It requires for dissolving it 1000 parts of cold absolute alcohol, and 40 or 50 times its weight of ether. Oil of turpentine dissolves half its weight of it. It dissolves also in the fixed oils by the assistance of heat. Acids scarcely act upon this resin, and it does not seem capable of combining with the caustic alkalies.

According to Lucanus, when 2 parts of dammara are agitated with $2\frac{1}{2}$ parts of oil of turpentine a varnish is formed, which answers much better for lithographic engravings than ordinary mastic varnish, being transparent, more durable, and less coloured.*

SECTION XIII.—OF RESIN OF JALAP.

This resin is obtained by digesting the root of the *convolvulus jalappa* in alcohol, and mixing the alcoholic solution with water, and distilling off the alcohol. It has a brownish-yellow colour and little lustre. It is opaque, brittle, and has a bitter and acrid taste. When heated or rubbed, it exhales the odour of jalap.

It is very soluble in alcohol. The solution, digested with animal charcoal and filtered, is rendered nearly colourless. When it is now precipitated and melted, it has a yellow colour. Ether dissolves about $\frac{3}{10}$ths of its weight of it. The portion dissolved remains after the ether is evaporated in the state of a deep brown resin, which it is difficult to dry completely. It dissolves in caustic soda, and the solution is not precipitated by sulphuric acid. But the portion insoluble in ether is precipitated when we saturate its solution in soda with sulphuric acid.

It is obvious, from this, that the resin of jalap consists of two resins. It dissolves completely in acetic ether and acetic acid. But it is insoluble in the fixed and volatile oils.

Herberger assures us that the resin of jalap dissolved in alcohol, and mixed with an alcoholic solution of acetate of lead, gives a solution of resinate of lead. The acid resin, which, in this case, combines with the oxide of lead, has not been examined. A great part of the resin is not precipitated.

The solution, freed from acetic acid, oxide of lead, and alcohol, gives a transparent colourless resin, very soluble in alcohol. Concentrated acetic acid dissolves it completely with the assistance of heat. Sulphuric, nitric, phosphoric, and muriatic acids do not dissolve it. Herberger has given it the name of *jalappin*, and considers it as an alkaloid. But its alkaline properties have not been sufficiently established.†

It is believed that scammony, the highest priced of the cathartic gum resins is sometimes adulterated by an admixture of the resin of jalap. M. Planche has pointed out a way by which this adulteration may be detected.‡ When scammony is triturated with milk in a mortar, an emulsion is formed, and the whole scammony is held suspended. But when the resin of jalap is treated in the same way, the particles are united into a solid mass. This is the case also with the resin of *colystegia soldanella*, used in France as a purgative.

SECTION XIV.—OF BENZOIN.

This substance is the produce of the *styrax benzoe*, a tree which

* Berzelius, Traité de Chimie, v. 501.
† Jour. de Pharm. xvii. 227. ‡ Ibid. xviii. 181.

grows in Sumatra, &c., and which has been described by Mr Dryander.* Benzoin is obtained from this tree by incision; a tree yielding 3 or 4 pounds. It is a solid brittle substance, sometimes in the form of yellowish-white tears joined together by a brown substance, and sometimes in the form of a brown substance not unlike common rosin. It has a very agreeable smell, which is increased by heating the benzoin. It has little taste. Its specific gravity is 1·092. This substance has been used in medicine for ages, and various processes have been pointed out by chemists for extracting benzoic acid from it.

It was examined chemically a good many years ago by Mr Brande,† and more lately by Unverdorben, to whom we are indebted for so much of our knowledge of resinous substances.‡

Cold water has very little effect on benzoin, but boiling water takes up a portion of benzoic acid.

Alcohol dissolves it when assisted by a gentle heat, and forms a deep yellow solution inclining to reddish-brown. When this solution is diluted with water, the benzoin precipitates in the form of a white powder. It is precipitated also by muriatic and acetic acids, but not by the alkalies. A few drops of sulphuric acid likewise precipitate the benzoin; but an additional quantity redissolves it, and forms a liquid of the colour of port wine. When equal quantities of the alcoholic solution of benzoin and sulphuric acid are mixed, a dark-pink precipitate falls. The liquid assumes a pink colour, which becomes lilac when diluted with water. Nitric acid occasions a strong effervescence, and forms a dark-red fluid with the alcoholic solution, but throws down no precipitate.§

Ether dissolves benzoin with facility, and the solution with reagents exhibits the same phenomena as the alcoholic.‖

Nitric acid acts with violence on benzoin, and converts it into an orange-coloured mass. When assisted by heat the acid dissolves the benzoin; and as the solution cools, crystals of benzoic acid gradually separate. Mr Hatchett ascertained that by this process a quantity of artificial tannin is formed.

Sulphuric acid dissolves benzoin, while benzoic acid (as Hatchett discovered) sublimes; the solution is at first a deep red. By continuing the digestion, a portion of artificial tannin is formed, and the charcoal evolved amounts to 0·48 of the benzoin dissolved.¶

Acetic acid dissolves benzoin without the assistance of heat. When heat is appplied, the solution, as it cools, becomes turbid, owing to the separation of benzoic acid.**

Benzoin is dissolved by a boiling lixivium of the fixed alkalies; a dark-brown solution is formed, which becomes turbid after some

* Phil. Trans. 1787, p. 307. † Nicholson's Jour. x. 82.
‡ Poggendorf's Annalen, xvii. 179.
§ Brande, Nicholson's Jour. x. 82. ‖ Ibid. x. 82.
¶ Hatchett, Third Series of Experiments on Artificial Tannin.
** Brande, Nicholson's Jour. x. 85.

days' exposure to the air. Ammonia likewise dissolves benzoin sparingly.*

Unverdorben subjected benzoin to an analysis, and found it to contain, besides benzoic acid, and a little volatile oil, three different resins, which he distinguishes from each other, by naming them *resins a*, *b*, and *c*.

If we reduce benzoin to powder, and boil it in an excess of carbonate of potash, the benzoic acid and a resin are dissolved, and may be precipitated by adding muriatic acid to the solution. When we boil this precipitate in water, the benzoic acid, and a little extractive are dissolved, and the resin remains, amounting only to $\frac{1}{300}$th of the benzoin employed. This is *resin c*.

The principal part of the benzoin does not dissolve in the carbonate of potash. A light brown-coloured matter remains. When it is digested in ether one resin is dissolved, and the other remains. The first part of these is *resin a;* the second, *resin b*.

1. *Resin a* remains when the ethereal solution is evaporated to dryness. It is very soluble in alcohol and oil of carvi; but insoluble in naphtha. It does not decompose acetate of copper, but it dissolves readily in potash, and an excess of that alkali does not precipitate it from its solution. Ammonia does not dissolve it. Its combinations with earths and metallic oxides are insoluble in ether.

2. *Resin b*, when washed with ether and dried, has a brown colour. It is soluble in alcohol, but insoluble in the volatile oils. Caustic ammonia does not dissolve it; but caustic potash dissolves it with facility. An excess of alkali throws down the resinate of potash formed.

When *resins a* and *b* are precipitated by an acid from their solution in potash, and exposed to the air while still moist, they are converted into *resin c*. When they are distilled *per se*, they give out a volatile oil, slightly empyreumatic, which, like the oil of bitter almonds, is converted by exposure to the air into benzoic acid.

3. *Resin c* has a deep-brown colour. It is soluble in alcohol of 0·875, and in more concentrated alcohol. It is little soluble in ether and volatile oils, and insoluble in naphtha. It possesses weak acid properties: it does not decompose acetate of copper, but it precipitates acetate of lead. Carbonate of potash dissolves it slowly. The resinate of potash is soluble in absolute alcohol, but insoluble in ether and oil of turpentine. Its solution in water is precipitated by sal ammoniac. The resinate of copper, obtained by double decomposition, is insoluble in ether and oil of turpentine.

M. Dulong d'Astafort has observed that resin of benzoin strikes a fine red colour with sulphuric acid.† This observation had been made long before by Mr Hatchett.

SECTION XV.—OF ANIMÉ.

This resin is obtained from the *hymenæa courbaril*, or locust tree,

* Brande, Nicholson's Jour. x. 86. † Jour. de Pharmacie, xii. 33.

which is a native of Cayenne. Animé resembles copal very much in its appearance; but it is easily soluble in alcohol, which copal is not: this readily distinguishes them. It is said to be very frequently employed in the making of varnishes. Alcohol dissolves it completely. Water, according to the experiments of Neumann, dissolves about $\frac{1}{16}$th of it; and when the decoction is evaporated, it leaves an unctuous mass, which makes the fingers oily. Alcohol distilled over it acquires both the smell and taste of animé. Water distilled from it shows on its surface a small quantity of volatile oil.*

When animé is digested in cold alcohol, a portion remains undissolved. This residue dissolves in boiling alcohol, and crystallizes as the solution cools, or by evaporation if the solution was not saturated. These crystals are colourless, and may be sublimed. Bonastre gives them the name of *subresin*, but their characters have not been investigated.

Animé contains a minute portion of volatile oil, to which it is indebted for its agreeable odour.

SECTION XVI.—OF COPAL.

This resin, by far the most important of the whole class, flows spontaneously from the *rhus copalinum* and *elæocarpus copaliferus*. The first of these trees grows in America, the second in the East Indies. A third species is said to exist on the coast of Guinea, especially near rivers, and it is collected from the sand on the shore. From Dr Roxburgh's account, it appears that the East Indian tree, *valeriea indica*, yields a resin possessing intermediate properties between copal and amber.†

Copal is a beautiful white resinous substance, with a slight tint of brown. It is sometimes opaque, and sometimes almost perfectly transparent. When heated it melts like other resins; but it differs from them in not being soluble in alcohol, nor in oil of turpentine without peculiar management. Neither does it dissolve in the fixed oils with the same ease as the other resins. It resembles gum animé a little in appearance; but is easily distinguished by the solubility of this last in alcohol, and by its being brittle between the teeth, whereas animé softens in the mouth.‡ The specific gravity of copal varies, according to Brisson, from 1·045 to 1·139. I found it 1·069. Mr Hatchett found it soluble in alkalies and nitric acid with the usual phenomena; so that, in this respect, it agrees with the other resins. The solution of copal in alkalies he found indeed opalescent, but it is nevertheless permanent. It deserves attention, that he found rosin, when dissolved in nitric acid, and then thrown down by an alkali, to acquire a smell resembling that of copal.

* Neumann's Chem. p. 297.

† Nicholson's Jour. xxvii. 72. It is stated in the Journal de Pharmacie (xxii. 522), that the true copal of Madagascar comes from the *hymenæa verrucosa*; the copal of India from the *trachylobium hornemannianum* of Hayne, and the copal of Brazil from the *trachylobium martianum* of Hayne.

‡ Lewis, Neumann's Chem. p. 299.

When copal is dissolved in any volatile liquid, and spread thin upon wood, metal, paper, &c., so that the volatile menstruum may evaporate, the copal remains perfectly transparent, and forms one of the most beautiful and perfect varnishes that can well be conceived. The varnish thus formed is called *copal varnish*, from the chief ingredient in it. This varnish was first discovered in France, and was long known by the name of *vernis martin*. The method of preparing it is concealed; but different processes for dissolving copal in volatile menstrua have been from time to time made public. The following are the most remarkable of these:—

When copal is kept melted till a sour smelling aromatic odour has ceased to proceed from it, and then mixed with an equal quantity of linseed oil, which has been deprived of all colour by exposure to the sun, it unites with the oil, and forms a varnish which must be dried in the sun.*

I have been informed by a very ingenious japan manufacturer in Glasgow, that the copal varnish used by the English japanners is made as follows:—Four parts by weight of copal in powder are put into a glass matrass and melted. The liquid is kept boiling till the fumes, condensed upon the point of the tube thrust into a matrass, drop to the bottom of the liquid without occasioning any hissing noise, as water does. This is a proof that all the water is dissipated, and that the copal has been long enough melted. One part of boiling-hot linseed oil (previously boiled in a retort without any litharge) is now poured into it, and well mixed. The matrass is then taken off the fire, and the liquid, while still hot, is mixed with about its own weight of oil of turpentine. The varnish thus made is transparent, but it has a tint of yellow, which the japanners endeavour to conceal by giving the white ground on which they apply it a shade of blue. It is with this varnish that the dial plates of clocks are covered after having been painted white.

When copal is treated with oil of turpentine in close vessels, the vapour, being prevented from escaping, exerts a greater pressure, and the heat rises above the boiling point. This additional heat is said to enable the oil to dissolve the copal. The solution, mixed with a little poppy oil, forms a varnish which is distinguished from the *vernis martin* merely in having a very slight tinge of brown.†

The method of dissolving copal in oil of turpentine, published by Mr Sheldrake, seems to depend upon the same principle with the last solution. On 2 ounces of copal, broken into small pieces, is poured a mixture of 4 ounces of ammonia with a pint of oil of turpentine. The whole is kept boiling very gently, so that the bubbles may be counted as they rise. If the heat be allowed to diminish, or if it be raised too high, the process stops, and cannot be again resumed. The matrass, in which the mixture is boiled, is stopped with a cork, secured in its place by a brass wire, and perforated by a pin. When the copal is nearly dissolved, the process

* Dr Black's Lectures, ii. 359. † Ibid.

is stopped, and the whole allowed to cool before uncorking the matrass. This varnish has a deep colour; but when spread thin and allowed to dry, it becomes colourless. Its defect is the difficulty with which it dries. This defect Mr Sheldrake remedies by throwing the solution into its own weight of nut oil, rendered drying by white lead, and agitating till the turpentine is separated.

To dissolve copal in alcohol, Mr Sheldrake dissolves half an ounce of camphor in a pint of that liquid, and pours the solution on four ounces of copal. The matrass is placed in a sand bath, and the process is conducted exactly as the one last described. The solution thus formed contains a great deal of copal, and forms a varnish which is perfectly colourless; but considerable heat is necessary to drive off the camphor.

Mr Sheldrake has favoured the public with another and easier method of dissolving copal. This method is as follows:—

"Provide a strong vessel made of tin or other metal; it should be shaped like a wine bottle, and capable of holding two quarts; it will be convenient to have a handle strongly riveted to the neck; the neck should be long and have a cork fitted to the mouth, but a notch or small hole should be made in the cork, that when the spirit is expanded by heat, a small portion may force its way through the hole, and thus prevent the vessel from bursting.

"Dissolve half an ounce of camphor in a quart of spirit of turpentine, and put it into the vessel; take a piece of copal the size of a large walnut, reduce it to a coarse powder or very small pieces; put them into the tin bottle, fasten the cork down with a wire, and set it as quick as possible upon a fire so brisk as to make the spirit boil almost immediately; then keep it boiling very gently for about an hour, when so much of the copal will be dissolved as will make a very good varnish; or, if the operation has been properly begun, but enough of copal has not been dissolved, it may be again put on the fire, and by boiling it slowly for a longer time, it may be at last brought to the consistence desired."*

Van Mons relates another process much simpler than any of the above, which he says was taught him by Mr Demmenie, a Dutch artist. It consists in exposing copal to the action of the steam of alcohol. A long-necked matrass is filled $\frac{1}{4}$th full of strong alcohol, and a piece of copal is suspended above the surface of the liquid at some little distance; the top of the matrass is covered with a condensator; the alcohol is kept boiling: the copal softens, and drops down into the alcohol like oil. When these drops no longer dissolve, the process must be stopped. The solution thus obtained is perfectly colourless. Copal may be dissolved in oil of turpentine by the same process.†

The following method of making copal varnish has been recommended by Professor Lenormand:—Drop upon the pieces of copal pure essential oil of rosemary. Those pieces that are softened by

* Nicholson's Jour. ix. 157. † Ibid. xxiv. 67.

the oil are fit for the purpose, the others not. Reduce them to a fine powder, put this powder into a glass vessel not thicker than a finger breadth, pour oil of rosemary over it, and stir it about with a glass rod. In a short time the whole is converted into a very thick liquid. Pour alcohol on this liquid by little at a time, incorporating it, by gently agitating the vessel, till it is of the requisite thinness for use.*

Unverdorben assures us that copal dissolves when we digest, for 24 hours, 1 part of it in $1\frac{1}{2}$ parts of alcohol, because the portion of copal which is insoluble in alcohol dissolves in a very concentrated solution of the soluble portion. Naphtha dissolves the 100th part of its weight of this resin, and oil of turpentine dissolves rather more.

Unverdorben has analyzed the African copal, and has extracted from it no fewer than five different resins. His method of analysis was this :—1. He reduced the copal to powder, and digested it in alcohol of 0·879, till every thing soluble was taken up. 2. The residue was digested in absolute alcohol, till every thing soluble in that liquid was taken up. 3. The residual matter was treated with half its weight of hydrate of potash dissolved in alcohol of 0·855. 4. What remained was a compound of resin and potash, which when digested in alcohol of 0·967 left a new residue. Thus the substances extracted from the copal were distributed in four divisions.

1*st Division.* The solution in alcohol of 0·879, contained two resins. They are precipitated in combination with oxide of copper, by pouring an acoholic solution of acetate of copper into the liquid containing them. When the precipitate is digested in ether the resinate of copper containing *resin a* dissolves, while the resinate containing *resin b* remains undissolved. If we dissolve them in alcohol acidulated with muriatic acid, and add water to the respective solutions, the two resins fall freed from the oxide of copper.

(1.) *Resin a* is colourless and soft, owing to the presence of a small quantity of volatile oil, which is easily disengaged by boiling the resin with water, or by cautiously fusing it. It is then hard. It melts at 212° ; and dissolves in all proportions in alcohol of 0·867. When precipitated from that solution by water, it has the fluidity of a fixed oil, and contains combined alcohol, which can only be separated by long boiling in water or by fusion.

This resin possesses the properties of an acid, and forms salts. The resinate of potash is colourless. By an excess of caustic potash it is precipitated in the state of a viscid mass from the concentrated solution, and in a gelatinous or mucous state from a diluted solution. It dissolves slowly in cold water, rapidly in hot water.

The resin dissolves in ammonia, forming a mucilaginous liquid, which may be boiled for a little without allowing the whole of the resin to precipitate. The resinates of the earths and metallic oxides may be formed by double decomposition. They are insoluble in alcohol ; but most of them are soluble in ether.

* Jour. de Chim. iii. 218.

(2.) *Resin b* has a striking resemblance to the preceding resin. But it does not melt at 212°, and its compounds with the metallic oxides are insoluble in ether. It does not dissolve in alcohol of 0·879, but absorbs a certain quantity of it, and becomes viscid and white. When boiled in water it loses the alcohol absorbed, and remains in the state of a coherent, porous, brittle mass. It is soluble in absolute alcohol and in ether, but does not dissolve in oil of turpentine and the fixed oils. It dissolves readily in caustic potash. An excess of alkali precipitates the resinate of potash in a viscid mass.

The resinate of potash is soluble in water and in alcohol, but insoluble in ether and oils.

Ammonia dissolves this resin into a thick but transparent liquid. When boiled it becomes muddy, but the resinate is not precipitated. By spontaneous evaporation we obtain the resinate of ammonia in a transparent state. The resinates of earths and metallic oxides may be obtained by double decomposition. They constitute viscid masses insoluble in alcohol and in ether. When we boil a mixture of resinate of potash and protochloride of gold, we obtain a red-coloured resinate of gold, which dissolves in potash or ammonia, and is thrown down unaltered from these solutions by an acid.

2*d Division.* The residue left by alcohol of 0·879, is a viscid mass. When it is boiled in absolute alcohol, a great deal of *resins a* and *b*, and at the same time another resin, which we may call *resin c*, are dissolved. If we mix the alcoholic solution with a concentrated alcoholic solution of potash, adding this solution in excess, a precipitate falls, consisting chiefly of *resin c*, combined with potash; though it contains a little of *resin b*. To separate these two resins we dissolve the resinate of potash in boiling water, and precipitate the liquid while hot by sulphuric acid; wash the precipitate, dry it and treat it with absolute alcohol. The *resin b* will be dissolved, and *resin c* left.

3*d Division.* The viscid residue insoluble in absolute alcohol is boiled with half its weight of hydrate of potash dissolved in alcohol of 0·857. Only the resinate of potash formed by *resin c* is dissolved. If we saturate the boiling hot solution with sulphuric acid, the *resin c* precipitates in fine powder.

(3.) *Resin c* possesses the following properties:—It is a powder and cannot be melted without, at the same time, undergoing decomposition. When heated in a retort it begins to swell at 662°, and begins to be charred at the same time. It seems to contain no combined water. It does not dissolve in absolute alcohol, but it absorbs a quantity of it and becomes viscid. It is very soluble in ether and oil of cajeput; but it does not dissolve in oil of turpentine unless it has been previously melted. Its resinate of potash is viscid when in the state of a concentrated solution. When dried it is a transparent gummy mass, which does not dissolve in water whether cold or hot. But it dissolves in water to which a little alcohol has been added, and continues dissolved though the alcohol

be driven off by evaporation. A very slight excess of alkali throws down the resinate in a gelatinous state; but a great excess is requisite to throw it down from its alcoholic solution.

This resin does not dissolve in ammonia, unless we add a little alcohol to the ammoniacal liquid. And we may evaporate away the alcohol and excess of ammonia without rendering the solution muddy.

When sal ammoniac is added to a solution of resinate of potash, or resinate of ammonia, the resin is precipitated in a gelatinous state. The resinates of the earths and metallic oxides are gelatinous and insoluble in water, alcohol, ether, and oils. But they are slightly soluble in an ethereal solution of *resin c*.

4th Division. The residue of copal from the preceding division, is digested in boiling hot alcohol of the specific gravity of 0·967. It leaves a residue amounting to about 8 per cent. of the copal employed. The weak alcohol dissolves a resinate of potash insoluble in stronger alcohol, and when the solution is mixed with muriatic acid it coagulates into a jelly, which deposits, on boiling, a resin in powder, which may be collected on a filter, washed and dried. It constitutes *resin d*.

(4.) *Resin d* is a white farinaceous powder, which cannot be melted. At 212° it gives out a little water; at 572° it gives out a great deal and concretes together. At a higher temperature it swells and is charred without melting.

It is completely insoluble in absolute alcohol, ether, and oil of turpentine; nor is it altered by any of these liquids. But after being softened by heat it dissolves in oil of turpentine. It is insoluble in an aqueous solution of caustic potash, but it is transformed into resinate of potash, which is insoluble in boiling water, but soluble in alcohol of 0·967, and precipitated from that solution in a gelatinous state, both by water and alcohol. The alcohol may be driven off from the solution in the weak spirit, without the resinate precipitating. By evaporation it becomes thick and gelatinous, and at last dries into a matter like gum, insoluble in water, and in alcohol stronger than 0·967.

Pure *resin d* is not acted on by ammonia; but when it is mixed with other resins it may be dissolved along with them in the ammoniacal liquor. Sal ammoniac poured into a solution of resinate of potash, throws down the resin in a gelatinous state, and free from ammonia. The compounds of this resin with earths and metallic oxides, obtained by double decomposition, are gelatinous while moist, and insoluble in alcohol, ether, and oils.

(5.) *Resin e.* The residue insoluble in spirits of the specific gravity 0·967 is gelatinous, and consists of a resin quite different from the preceding, which may be called *resin e*. While drying it agglutinates into a compact, infusible mass, which when heated gives out a good deal of water. It is insoluble in alcohol, ether, and oils, and neither combines with acids nor bases. It is therefore a neutral resin.

From the preceding analysis we see that when copal is treated

with boiling caustic potash, the portion dissolved consists of *resins a* and *b*, while all the other resins are in the coagulated portion. Unverdorben has observed, that, when *resins d* and *e* are kept in a phial, not filled, under absolute alcohol, especially if a little ether be added, they absorb oxygen, and are gradually converted into *resins a*, *b*, and *c*. So that after a month *resins d* and *e* are no longer to be found. Copal in powder gradually undergoes a similar change. Probably as the copal flows from the trees that yield it, only *resins d* and *e* are contained in it, and *resins a*, *b*, and *c*, are gradually formed by the action of the air.

Unverdorben has also analyzed copal which has been fused. When we heat copal till it is liquid, and dissolves in oil of turpentine, it gives a very volatile oil, and a moderately volatile oil, intermediate between a volatile and empyreumatic oil. Towards the end of the distillation, resinous matter passes over. Fused copal still contains *resins a* and *b*, but the other resins are altered and we find in their place resins which are soluble in oil of turpentine. Alcohol of 0·879 extracts from fused copal the *resins a* and *b*. Absolute alcohol, being boiled in the residue, does not dissolve it completely. The liquid becomes muddy during the cooling, and deposits a viscid resin, which retains a little alcohol, and dissolves readily in ether and oil of turpentine. It is a moderately-acid resin. The alcohol becomes clear and cold, contains in solution the greater part of the melted copal, and leaves when evaporated *resin c* of melted copal. It possesses the following properties :—

It is very soluble in alcohol of the specific gravity 0·832, and in absolute alcohol, also in oil of turpentine and the fixed oils. Combined with half its weight of alcohol, it has the appearance of an oil at the temperature of 185°, but at the ordinary temperature of the atmosphere it is a solid friable resin. Heat drives off the alcohol and leaves pure resin. It combines easily with potash. The resinate of potash is insoluble in alkaline water, but dissolves slowly in cold water, and more rapidly in boiling water. It dissolves also in alcohol, but is insoluble in ether. When dry it resembles gum. With the earths and alkalies it forms combinations which concrete at 212°, and are not soluble in ether or in oils.

The portion of melted copal insoluble in absolute alcohol may be called *resin d*. It possesses some of the properties of the *resin d* of unmelted copal. It is hard and brilliant, and not viscid at 212°. It is very soluble in ether, oil of turpentine, and the fixed oils. With boiling alcohol it forms a viscid compound, insoluble in alcohol, brittle when cold, and letting go the alcohol when heated. Potash and ammonia combine with this resin without dissolving it. Alcoholic water dissolves the resinate of potash, and the solution continues after all the alcohol is driven off. This resinate is but little soluble in absolute alcohol, and the small quantity dissolved by boiling precipitates when the alcohol cools. This property of *resin d* enables us to get it free from all mixture of *resin c*. For when a mixture of the two resinates of potash is treated with absolute alco-

hol, all the resinate of *c* dissolves, while the resinate of *d* remains. When we pour a dilute acid on the resinate of potash, the *resin d* separates in the form of a jelly. This resin forms with earths and metallic oxides pulverulent compounds, which are insoluble in alcohol and ether.

SECTION XVII.—OF HIGHGATE RESIN.

This substance was dug up at Highgate, near London, during the attempt, in 1813, to run a tunnel through the hill. It was in small amorphous masses of different sizes. Colour a muddy yellowish light-brown. Semitransparent. Lustre resinous, and surface smooth, as if it had been long agitated in water. It was less easily broken than common rosin, but much more easily than copal. Softer than copal. Has a resinous and aromatic smell, especially when heated. When heated it melts, and may be rendered as liquid as water, without altering its colour. When in lumps it is insoluble in water, alcohol, potash ley, acetic acid; but ether renders it opaque and white, and quite tender. It loses its cohesion and crumbles into powder upon the least pressure between the fingers. The ether at the same time dissolves a portion, which it deposits when mixed with water. Nitric acid partly dissolves and partly converts it into a red-coloured substance. Water throws down the dissolved portion in the state of bitter-tasted white flocks. Sulphuric acid readily chars it when assisted by heat. When in a state of a fine powder, alcohol dissolves a small portion of it. It is insoluble in potash ley.*

SECTION XVIII.—OF LAC.

This important resin is deposited in different species of trees in the East Indies, namely, the *ficus indica*, *ficus religiosa*, and *rhamnus jujuba*. It flows out in the state of a milky liquid, in consequence of the puncture of a small insect, the *coccus ficus*, on the branches of these trees, made by the insect in order to deposit its ova. It has been imported into Europe, and extensively used from time immemorial; but it is only of late years that correct information concerning it has been obtained. For what relates to the natural history of the insect, and the mode of forming the lac, we are indebted to Mr Ker,† Mr Saunders,‡ and Dr Roxburgh.§ Though very often employed in the arts, it was neglected by chemists. Geoffroy, junior, indeed, published a dissertation on it, but it contains few chemical experiments. He merely subjected it to distillation, and obtained products which he thought similar to those given by wax in the same circumstances.‖ This led him to consider it as a species of wax, an opinion followed by Neumann;¶ but Junker,** and most of the subsequent chemical writers, place it among the

* Annals of Philosophy, ii. 9. † Phil. Trans. 1781, p. 376.
‡ Phil. Trans. 1789, p. 107. § Ibid. 1791, p. 228.
‖ Mem. Par. 1714, p. 121; and Martine's translations of the Memoires of the French Academy, v. 4.
¶ Chemistry, p. 334. ** Conspectus Chemiæ, ii. 70.

resins. Mr Hatchett has examined it with his usual address, and ascertained its composition and properties.* A very important analysis of it was published by Unverdorben in 1828.† We are indebted also to Berzelius for some experiments on it.

There are various kinds of lac distinguished in commerce. *Stick lac* is the substance in its natural state, encrusting small twigs. When broken off and boiled in water it loses its red colour, and is called *seed lac*. When melted and reduced to the state of a thin crust, it is called *shell lac*. Stick lac is of a deep red colour, and yields to water a substance which is used as a red dye. The other two varieties are brown.

Water dissolves the greatest part of the colouring matter of lac, which varies from 15 to $\frac{1}{2}$ per cent. Alcohol dissolves the greatest part of the resin, which constitutes the chief ingredient in the composition of lac. Ether acts more feebly. Sulphuric acid dissolves and gradually chars lac; nitric acid dissolves, and then produces the same changes on it as on other resinous bodies. Muriatic and acetic acids likewise act as solvents. A solution of borax in water readily dissolves lac. The best proportions are 20 grains of borax, 100 grains of lac, and 4 ounces of water. This solution, mixed with lamp black, constitutes Indian ink; and may indeed be employed for many of the purposes of varnish. The fixed alkalies readily dissolve lac, but not the volatile. When placed on a hot iron it melts, and emits a thick smoke with an odour rather pleasant, leaving a spongy coal. When distilled, it yields water slightly acidulous, and a thick butyraceous oil. The gases emitted are a mixture of carbonic acid and carburetted hydrogen. Stick lac yields also some carbonate of ammonia; but the other two varieties none. The following table exhibits the constituents of the different varieties of lac, according to the analysis of Mr Hatchett:—

	Stick Lac.	Seed Lac.	Shell Lac.
Resin . . .	68	88·5	90·9
Colouring matter .	10	2·5	0·5
Wax . . .	6	4·5	4·0
Gluten . . .	5·5	2·0	2·8
Foreign bodies .	6·5	—	—
Loss . . .	4·5	2·5	1·8
	100·5	100·0	100·0

The resin is less brittle than those bodies usually are. The colouring matter possesses the properties of extractive; the wax is analogous to myrtle wax, and the gluten closely resembles the gluten of wheat.‡

Dr John published a set of observations on stick lac in 1810, and drew, as a conclusion, that it consists of three distinct substances,

* Analytical Experiments on Lac, Phil. Trans. 1804.
† Poggendorf's Annalen, xiv. 116. ‡ Hatchett, Phil. Trans. 1804.

viz., a colouring matter, a peculiar body to which he gave the name of *laccin*, and resin.*

In the year 1816, a very elaborate analysis of stick lac appeared by the same chemist. According to him, 120 grains of stick lac are composed of the following substances:—

Resin, insoluble in ether	80
Laccin	20
Cochenillin	4·5
Extractive	3
Yellow extract	0·5
Laccic acid	0·75
Cochenil coloured coverings of insects	2·5
Waxy tallow	2
Laccate of potash, Sulphate of potash, Muriate of potash, Phosphate of lime, A salt of iron	1·25
Earthy matter	0·75
Loss	4·75
	120·00

The *laccin* was the matter that remained after the lac had been repeatedly digested in alcohol and water, till nothing further could be removed. It is distinguished by the following characters:—

It is hard and brittle, has a yellow colour, and a certain degree of transparency. It is insoluble in cold water; but in hot water, though it does not dissolve, it becomes soft. In cold alcohol it softens, increases in bulk, and acquires a slippery feel. Even hot alcohol is unable to dissolve it. In ether and essential oils it swells a little, and becomes quite transparent, but does not dissolve.

It dissolves very readily in potash ley, and the solution has a light-brown colour. Muriatic acid renders the solution milky, and the laccin slowly precipitates. Concentrated sulphuric acid dissolves it very rapidly; the solution has an amethyst colour, and becomes muddy when mixed with water. When long boiled with water, containing from $\frac{1}{16}$th to $\frac{1}{8}$th of its weight of sulphuric acid, only a small portion of it is dissolved. This portion is obtained in the state of a yellowish gum, when the acid is separated by means of lime, and the solution evaporated. This property distinguishes it readily from cerasin. Concentrated nitric acid dissolves it slowly when assisted by heat. The solution is clear, and has a yellow colour, without any bitter taste. It gradually deposits some crystals of oxalic acid. Diluted nitric acid has no effect on it either cold or hot.

When heated, laccin gives out an aromatic odour, and becomes soft. It does not melt, but is gradually charred. When distilled, it gives out water, an acid, which, when saturated with soda, throws

* Chemische Untersuchungen, i. 52.

down muriate of iron white, and a yellow and brown oil. No ammonia can be detected in the products of the distillation.*

But the analysis of Unverdorben deserves peculiar attention. He had made resinous bodies his particular study, and was able, therefore, to detect its various constituents with more address than his predecessors. He found in lac the following substances:—1. A resin soluble in alcohol and ether, which may be called *resin a* of lac. 2. A resin soluble in alcohol, but insoluble in ether, *resin b*. 3. A resinous-looking substance, a little soluble in cold alcohol, *resin e*. 4. A crystallizable resin, *resin c*. 5. A resin soluble in alcohol and ether, but insoluble in naphtha and uncrystallizable, *resin d*. 6. Fat of coccus not saponified, together with some oleic and margaric acid. 7. Wax. 8. *Laccin* of John. This substance is not found in shell lac. 9. A *red colouring* matter. His mode of analysis was the following:—

I. If we digest purified lac in boiling alcohol of 0·879, till every thing soluble is taken up, and filter the solution while hot, it deposits, on cooling, a gelatinous matter, amounting to about 8 per cent. of the lac employed. This is *resin c*. The alcohol leaves undissolved about 8 per cent. of the lac.

II. The filtered alcohol solution is mixed with its own weight of water, and the alcohol being distilled off, the residue is evaporated to dryness. The resin which remains is digested in water till every thing soluble in that liquid is taken up. A substance is dissolved containing *resin a*. From this solution the resin is precipitated by phosphoric acid.

(1.) *Resin a* of lac possesses the following properties:—It is brown, easily melted, soluble in alcohol of 0·879, and in ether. But this last liquid does not dissolve it completely. It leaves a portion (doubtless a peculiar resin) soluble in alcohol of 0·879, and in caustic potash.

The ethereal solution when evaporated leaves *resin a* in a state of purity. It dissolves in caustic potash, which assumes a violet colour. The acetates of copper and lead precipitate its solution in alcohol. The resinates of copper and lead collect into a mass in boiling water. and are neither soluble in alcohol nor ether. Unverdorben informs us that *resinate a* of potash is decomposed by boiling, in such a manner that $\frac{1}{3}$d of the resin is converted into oleic and margaric acid.

Lac does not contain more than half a per cent. of *resin a*.

III. The residue insoluble in water, proceeding from the alcoholic solution of lac, diluted with water and distilled, is dissolved in a quantity of absolute alcohol, equal to its own bulk, and mixed with eight times its volume of ether. This throws down a viscid preci-

* Chemische Untersuchungen, iv. 12.

pitate, which is *resin b* of lac, combined with ether. It loses its tarry consistence when the ether is evaporated away. Lac contains $\frac{7}{10}$ths of its weight of this resin.

(2.) *Resin b*, thus obtained, possesses the following properties:—

It is hard. It dissolves in cold alcohol of 0·860 or in stronger alcohol. When this solution is mixed with water and distilled, the resin precipitates in the state of a firm jelly. When put into boiling water it conglomerates into a resinous mass. When heated it melts and swells, giving out the odour of melted lac. It has the property of precipitating acetate of copper. The precipitate is a powder soluble in ether and oils, but insoluble in alcohol.

Resin b, while in solution in alcohol, decomposes carbonate of magnesia by the assistance of heat, and dissolves the magnesia. But the resinate of magnesia obtained by double decomposition is insoluble in alcohol.

The resinate of potash dissolves readily in water, and is not precipitated from its solution by an excess of potash. By means of it, brown-coloured resinates of the earths and metallic oxides may be obtained, which are insoluble in alcohol, ether, and the oils.

This resin, as well as *resin a*, has the curious property of dissolving without alteration in cold potash ley, and of being partly converted into oleic and margaric acid when the liquid is boiled. This, at least, is the opinion entertained by Unverdorben.

IV. The ethereal solution from which *resin b* had precipitated, is mixed with water and distilled. A resinous substance remains, which is dried and dissolved in a small quantity of ether. This solution is mixed with its own bulk of naphtha, and the ether is evaporated away. The greatest part of the resin now falls from the naphtha, which retains in solution the fat of the coccus, and a small quantity of resin. The weight of the resin, separated in this manner, does not exceed two per cent. of the weight of lac employed. It consists of two resins, which may be distinguished by the names *c* and *d*. To separate them from each other, dissolve them in the smallest possible quantity of potash, and mix the solution with sulphate of magnesia. When the precipitate that falls, consisting of the two resins combined with magnesia, is digested in caustic potash, the *resinate d* of magnesia is decomposed, and the *resin d* dissolved in the potash, while the subresinate of *resin c* remains under the form of a violet-coloured powder. The resins thus separated are thrown down, each, by muriatic acid, washed and dried.

(3.) *Resin c*, while in a state of fusion, is reddish-yellow by transmitted light, and black by reflected light, and has the aspect of a resin. When slowly cooled, or when its alcoholic or ethereal solution is evaporated, it is deposited in acicular crystals of an orange-yellow colour. The crystals become particularly bulky when muriatic acid has been added to the ethereal solution. At the temperature of 59°, it requires about 20 times its weight of ether or alcohol to dissolve it. At a boiling temperature it is much more soluble in

these liquids. Oil of turpentine dissolves it with difficulty cold, but more readily when hot, and when the solution cools the resin is deposited again in crystalline flocks. Concentrated sulphuric acid dissolves it, assuming a red colour, and does not decompose it unless raised to a boiling temperature.

Concentrated nitric and muriatic acids dissolve a small quantity of it which is precipitated by water. When assisted by heat, nitric acid decomposes it.

It possesses the properties of an acid in a very marked manner. With colourless bases it forms compounds, which are violet coloured when neutral; but brown when they contain an excess of resin. This explains why certain violet combinations become brown when exposed to the air, the carbonic acid of the atmosphere combining with a portion of the base. Hence the violet colour is restored by adding an additional quantity of the base in order to saturate the resin.

The resinate of potash dissolves readily in water. We may add a certain quantity of potash to the solution without throwing down the resinate; but a greater quantity causes it to precipitate. When the resinate of potash is dried, it assumes the appearance of a gum. It dissolves in boiling alcohol, but is deposited in a gelatinous state when the solution cools. Ether does not dissolve it, but it deprives it of the property of forming a red solution with water. After digestion in ether, it dissolves in water with a brown colour.*

By double decomposition, resinates of the earths and metallic oxides may be obtained, which are violet when the bases are colourless, and reddish-brown when these bases have a colour. They are powders, insoluble in ether and alcohol, decomposable by hydrate of potash, with the exception of resinate of magnesia. This last resinate may be obtained either by double decomposition or by boiling a solution of *resin c* with carbonate of magnesia. It is a powder having a violet colour.

Resin c may be extracted from lac, simply by boiling the alcoholic solution of the lac with carbonate of magnesia. It precipitates, when this is done, in combination with magnesia, from which it may be separated by muriatic acid.

(4.) *Resin d* is soft and flexible, and seems to contain some of the fat of the coccus. When heated to 212° it melts. It is very soluble in alcohol and ether. Potash and ammonia dissolve it, assuming a brown colour. When the ammoniacal solution is evaporated, the alkali is dissipated. Potash throws down the resinate of potash from its concentrated solution; the precipitate is brown and viscid. The resinate of copper is a powder, which does not dissolve in ether.

V. We must now speak of the gelatinous precipitate which falls during the cooling of the boiling alcoholic solution of lac, mentioned

* The red colour is doubtless owing to the presence of a little of the red colouring matter of lac, which is removed by the ether.

in paragraph I., and stated there to amount to about 8 per cent. of the lac employed. After having been washed with alcohol and dried, it is a hard, brown, porous body, with a resinous aspect. We shall call it *resin e*, because it has more analogy with the resins than with any other set of bodies.

(5.) *Resin e* may be kneaded in boiling water, but it does not fuse except at a high temperature, and while melting it undergoes decomposition, and is converted into a true resin. While cold, it is insoluble in alcohol, ether, and volatile oils. Potash dissolves it, assuming a brown colour. And, according to Unverdorben, a part of the resin is decomposed; for acids throw it down of the consistence of tar, from which ether extracts oleic and margaric acid, and resin. If we add naphtha to this ethereal solution, the resin precipitates, and the oily acids alone remain in solution.

Resin e dissolves also in ammonia mixed with a little alcohol, and this solution contains oleate and margarate of ammonia. The resinate of copper is brown, and insoluble in ether.

VI. The portion of lac insoluble in boiling alcohol, is the *laccin* of John, which has been described in a preceding part of this Section. It contains besides, a little wax, resin, and fat, besides foreign matters, such as fragments of wood, envelopes of coccus, &c. The wax may be separated by digestion in naphtha or ether. The *laccin* may be then dissolved by digestion in alcohol of 0·879, previously mixed with a little muriatic acid. Water is poured into this solution, the alcohol is distilled off, and the laccin remains mixed with a little resin. When dried and boiled, first in alcohol and then in ether, the resin is dissolved and the laccin remains.

Laccin extracted in this way was found by Unverdorben possessed of the following properties:—It was brown, brittle, translucent, composed of small particles conglomerated together, and has a greater resemblance to resin than to any thing else. At 212° it is not altered; but it melts at a higher temperature, swelling up and giving out the odour of lac. Its composition is then altered. It swells up a little in alcohol and ether; but does not dissolve. It is equally insoluble in the fixed oils. Alcohol, acidulated by sulphuric or muriatic acids, dissolves it by long-continued digestion, and water throws it down from this solution. But if we saturate the acid solution with carbonate of lime, the laccin, instead of being precipitated, is converted into two resins, soluble in alcohol, which have some analogy to *resins a* and *b* of lac.

Concentrated acetic acid, whether alone or mixed with alcohol, does not dissolve laccin. Caustic potash dissolves it by a boiling temperature, and converts it into *resins a* and *b*. If we add alcohol to the potash solution, this change takes place without the application of heat.

The great purpose to which lac is applied, is the making of sealing-wax. The best red sealing-wax is made by melting together, in a very gentle heat,

48 parts of shell lac
19 parts of Venice turpentine
1 part of balsam of Peru
32 parts of cinnabar, in fine powder

100

The fused mass, when cooled to a certain point, is cast in moulds.

In the cheaper kinds of wax the lac is replaced by rosin, and the cinnabar by red lead. The finest black sealing wax is made of

60 parts shell lac
10 parts turpentine
30 parts levigated ivory black

100

The colouring matter of yellow wax, is chromate of lead; that of blue sealing wax, cobalt or mountain blue; that of green wax, mountain green, or oxide of copper.

Lac is employed also to lute together broken stoneware vessels. It enters likewise as a frequent ingredient into varnishes.*

SECTION XIX.—OF AMBER.

This substance is undoubtedly of vegetable origin; and though it differs from resins in some of its properties, yet it agrees with them in so many others, that it may, without impropriety, be referred to them. For the chemical investigation of the properties of this substance, we are chiefly indebted to the labours of Hoffmann,† Bourdlin,‡ Stockar de Neuforn,§ Heyer,‖ and it has occupied the attention of Mr Hatchett. More recently its properties have been investigated by Berzelius,¶ and by Unverdorben.

The best account of amber varnish which I have seen is by Nils Nystrom, in the *Stockholm Transactions* for 1797.**

Amber is found in beds of wood coal, deposited in Greenland, Prussia, France, Switzerland, &c. At Trahenieres, in the Henegau, it is found in clay mixed with a certain quantity of the debris of wood nearly in the state of wood coal. The greatest part of the amber of commerce is found in Prussia, on the south shore of the Baltic, being thrown up from the sea between Konigsberg and Memel. It is supposed to be derived from beds of wood coal in the

* The reader will find a valuable set of experiments upon a spurious kind of lac, by MM. Nees von Esenbeck, and Clamor Marguart, in the Ann. der Pharmacie, xiii. 286.

† Obs. Phys. Chem. pp. 60 and 198. ‡ Sur le Succin. Mem. Par. 1742, p. 192.

§ Specimen. Chem. Med. Inaugur. de Succino in Genere et speciatim de Succino Fossili Wisbolzensi, 1760. This tract contains a very copious set of experiments; which, however, do not always agree with those of other chemists. Wasserberg's Treatise on Amber is chiefly an abridgment of Stockard's.

‖ Chemische versuche mit Bernstein, 1787.

¶ Ann. de Chim. et de Phys. xxxviii. 219.

** I have seen the paper only through the medium of Crell's Journal. It is inserted in Crell's Annals, 1799, ii. 171 and 253.

basin of the Baltic. It is cast ashore also in considerable quantities on the east coast of England. There seems no reason to doubt that amber proceeded originally from the trees which accompany it, and that it was a resin held in solution by a volatile oil. That it was at one time liquid, is obvious from the insects which are occasionally found buried in it. No living insect is known exactly similar to those found in amber; showing that a very long period must have elapsed since the trees vegetated from which it flowed.

Amber is a brittle, light, hard substance, usually nearly transparent; sometimes almost colourless, but commonly yellow or even deep brown. It has considerable lustre. Its specific gravity is 1·065. It is tasteless, and without smell, except when pounded or heated, when it emits a fragrant odour. When heated it softens; but, as far as is known, cannot be melted without losing some of its weight, and altering its appearance. In a strong heat it burns, leaving a small quantity of ashes, the nature of which has not yet been ascertained. Water has no action on it; but alcohol, by long digestion, dissolves about $\frac{1}{8}$th of the amber, and forms a coloured solution, which when concentrated becomes milky when mixed with water. The precipitate possesses the properties of a resin. The residuum of the amber is not acted on by alcohol. Though amber be roasted before the action of the alcohol, the tincture is still formed. Hence we learn that the resinous part of amber is not expelled by a melting heat.* When amber is treated with a boiling fixed alkali, it is almost completely dissolved, according to Hoffmann, and the compound possesses the qualities of soap; for it is soluble in water and alcohol, and not thrown down by water. Mr Hatchett found that the alkalies act only partially on amber, extracting a yellow tincture. Probably this ingenious chemist did not continue the process long enough; for I have accidentally ascertained, that a weak solution of potash is capable of dissolving amber completely without the assistance of heat, provided it be allowed to act for a sufficient time. I had formed a weak solution of potash (I believe carbonate) as nearly as possible of the specific gravity of amber, and I had put into it some amber powder, to show the supposed currents of Count Rumford during the heating of the liquid. On examining the infusion about a month after, I found the amber all lying at the bottom of the phial. I added more alkali to restore the equilibrium. Some time after the amber was again at the bottom, and it was necessary to add more alkali. By this time the solution had acquired a yellow colour. I therefore explained the sinking of the amber, by supposing that the potash had dissolved a portion of it, and that this had altered the specific gravity of the solution. Not knowing at the time that any experiments had been made on the subject, I put aside the phial to ascertain the result. Three years after only two or three particles of the amber at most could be detected, the rest having dissolved completely.

* Heyer.

The weaker acids have no action on amber. Sulphuric acid converts it into a black resinous mass. Nitric acid acts upon it; when assisted by heat, nitrous gas is emitted. The amber is first converted into a light resinous substance, and at last dissolves completely. Heyer, who first made this experiment, could obtain neither oxalic nor acetic acid by the action of nitric acid on amber. That nitric acid is really capable of dissolving amber has been verified by the experiments of Hatchett, who found it soluble with the same phenomena as resins in general.

Amber consists of a mixture of different substances; namely, 1, a volatile oil; 2 and 3, two resins soluble in alcohol and ether; 4, succinic acid; and 5, a bituminous substance, which resists the action of all solvents, and which constitutes the greater part of the amber. These principles may be separated from each other in the following way:—

Reduce the amber to a very fine powder, and digest it in a close vessel with ether, renewing the solvent till it ceases to dissolve any thing more. In this way about 10 per cent. of the amber may be dissolved. If we mix this solution, which is pale yellow, with water, and distil off the ether in a retort, we find swimming on the surface of the water in the retort a soft transparent resin, almost colourless when in very thin layers, and yellow when in quantity. This resin has a smell similar to that of amber while pounding. It adheres to the fingers. It gradually loses its viscidity, but long retains its softness and smell.

If we heat it while on the surface of the water after the ether has been distilled off, there passes slowly along with the water a little volatile oil, which dissolves in water. By this treatment the balsam is converted into a resin, which has a pale yellow colour, is opaque and brittle, and may be rubbed into powder between the fingers.

The water on which the resin swims in the retort is acid, and when left to spontaneous evaporation, deposits crystals of succinic acid. We see from this, that succinic acid exists ready formed in amber, and that it is not formed during the distillation. Indeed, Unverdorben has shown, that it may be extracted from amber by means of an alcoholic solution of potash.

The water found in the receiver, after the distillation, contains some drops of volatile oil; but furnishes no more of it when cooled down to 32°. It has a strong and agreeable odour, resembling at once oil of pepper and oil of rosemary. Its taste is at first cooling, then aromatic, and it leaves an impression of heat, which continues long.

The resin separated from the volatile oil is very fusible. In boiling water it softens, and unites into one mass. When fused, at an elevated temperature, it remains transparent after cooling. It dissolves readily in the alkalies when in excess. But the compound which it forms is insoluble in uncombined alkali. When the resinate solution is evaporated to dryness, it leaves a transparent varnish, partly soluble in water, while a portion remains, swelling into a mu-

cilaginous mass. This resinate is easily decomposed by means of an acid.

These two resins may be also separated from each other by digesting them in cold alcohol of 0·84, which dissolves the one, and leaves the greater part of the other. If we heat the alcohol, both the resins are dissolved; but one of them precipitates partly when the solution cools, and partly when it is left to spontaneous evaporation. Finally there remains a limpid yellow solution, which, when evaporated to dryness, leaves a soft limpid resin with a smell like volatile oil of amber. This resin melts at 212°. It is very soluble in alcohol and ether. It dissolves also in the alkalies, and the solution, which is yellow, gives, when evaporated, a transparent yellow mass, which is soluble in water and alcohol, but which deposits a mucilaginous matter, when it still retains an excess of resin. The solution of this resinate of potash is precipitated by potash. Muriatic acid throws down the resin in the state of a bulky gelatinous mass, almost white after being dried, and breaking with a vitreous fracture. When melted it gives out water and becomes yellow.

The resin which has been deposited in a pulverulent state, is more soluble in absolute alcohol. It enters with difficulty into fusion. When in fusion it is yellow, but on becoming again solid, it is quite transparent. It dissolves in the alkalies, and the solution, which is colourless, and which is precipitated by a new dose of alkali, gives, when evaporated, a white mass, opaque and swelling, and partly dissolving in water. The acids throw down the resin from this compound in the state of a hydrate, which is semitransparent, as long as it continues moist.

The portion of amber not soluble in ether may be called the *bitumen of amber*. It is insoluble in alcohol, the fixed and volatile oils, and in caustic alkalies. It has the form of a light yellow powder, possessing the principal properties of amber. When heated in a spoon, it becomes brown, giving out the smell of burning fat, but it does not melt. When heated in a distilling apparatus, it gives out a colourless empyreumatic oil, and melts into a deep brown mass; and if the distilling be continued, is almost totally converted into empyreumatic oil, having at first the smell of oil of wax, and ultimately that of oil of amber. A very little charcoal remains in the retort.

If we stop the process as soon as the bitumen of amber has entered into fusion, we obtain a resinous-looking mass, which, when cold, is transparent like rosin, when in small pieces. It is easily reduced to powder, and the powder is strongly electric. Alcohol, when digested on it, separates a small quantity of yellow resin, very fusible, and very little soluble in the alkalies. Ether digested on it, after the alcohol, extracts a considerable portion of matter, leaving a brown and viscid mass. When the ether is evaporated, there remains a hard transparent resin of a brownish-yellow colour.

The portion insoluble in ether dissolves both in oil of turpentine and in naphtha, with the exception of a yellow, transparent, elastic

substance, which is insoluble in all these liquids. After the evaporation of the oil, this insoluble matter becomes hard and brown, and has exactly the appearance of the original bitumen of amber.

When assisted by heat, oil of turpentine and the fixed oils dissolve easily the melted resin, but always leave untouched the elastic matter just mentioned. Absolute alcohol poured into the solution throws down the greatest part of the resin, and ether also occasions a precipitate, though less abundant.

The bitumen of amber has some resemblance to the substance formed when a current of chlorine passes through an alkaline solution of lac, and which remains when we dissolve the bleached resin of lac in alcohol. That substance, like bitumen of amber, when melted in a retort, gives a brown transparent resin, from which alcohol extracts a small quantity, and ether a larger quantity of matter, and which afterwards gives out to oil of turpentine a reddish-yellow resinous substance. The residue insoluble in that oil consists of a brown elastic matter, which hardens when dried, and appears to be a portion of the primitive matter unaltered.

The principal difference between the properties of the bitumen of amber, and of the substance from lac, is the solubility of this last substance in potash, which causes it to assume the characters of a resin. But if we mix the bitumen of amber with a solution of caustic alkali, and evaporate till the amber fuses in the hydrate of potash, there is disengaged a quantity of empyreumatic oil, and we obtain a resinate of potash, which yields to water the excess of alkali which it contains. The alkaline solution is colourless, and when neutralized by muriatic acid, it gives a small quantity of fusible precipitate, which has a strong smell of oil of amber, as long as any traces of succinic acid remains in the liquid. But this precipitate does not seem to consist of the bitumen of amber. It is rather a residue of the two other resins which had not been completely extracted from the coarse powder of amber.

The resinate of potash dissolves in pure warm water, with a brown colour, leaving unaltered the bitumen of amber. When the solution is evaporated we obtain a brown matter which does not adhere to the glass, and which, when redissolved in water, and mixed with muriatic acid, gives a greyish-white mucilaginous precipitate. This precipitate consists of a hydrate of the resin. It parts with its water when fused, and then is a deep-yellow hard and transparent resin, soluble in a small quantity of absolute alcohol. It dissolves very nearly in ether, and altogether in oil of turpentine.

Now that we know the constituents of amber, it will be easier to explain the way in which it acts with other bodies. *Water* has no action on it, or only extracts a small quantity of succinic acid.

Absolute alcohol dissolves the same substances as *ether*. But that these liquids may act, the amber must be in the state of a very fine powder. The alcoholic solution is light yellow, and when evaporated leaves a soft yellow transparent resin. If we pour water into the alcoholic solution it becomes milky, and continues so after the

distillation of the alcohol; yet it deposits a small quantity of pale yellow resin. When the milky liquid is evaporated to dryness, we obtain a pulverulent substance, which gives out to water succinic acid, and the residue, insoluble in water, consists for the most part of that pulverulent resin, which is but little soluble in cold alcohol. The aqueous solution gives, by evaporation, a pale yellow extractive matter, from which ammonia throws down a yellow substance insoluble in water. The filtered liquid, when evaporated, yields crystals of succinate of ammonia.

According to Unverdorben, amber in powder dissolves in concentrated sulphuric acid, which acquires a brown colour. When water is poured into this solution, the greatest part of the amber is thrown down. The precipitate contains a certain quantity of combined sulphuric acid, and when distilled, besides the ordinary products of amber, it gives out a little sulphuretted hydrogen gas. The portion of amber which the water does not precipitate from the acid solution, remains dissolved when the acid is neutralized. It resembles extractive, but is not precipitated by the salts of lead and tin.

If we boil a solution of amber in sulphuric acid, we obtain, as usual, artificial tannin and charcoal. Nitric acid converts amber into a resinous-looking substance, and afterwards dissolves it.

If, after having reduced amber, to a fine powder, we boil it in a solution of hydrate or carbonate of potash, the alkali dissolves very little resin, but a great quantity of succinic acid. By this process, rightly conducted, all the succinic acid might be extracted from amber without rendering it unfit to serve for making amber varnish after having been fused.*

SECTION XX.—OF PASTO RESIN.

Boussingault has described the characters of a resinous substance employed by the Indians at Pasto, in the northernmost parts of Peru, for covering wood and rendering it impermeable to water.† The plant which yields it is unknown. It is procured from Macao, seven days' journey east from Pasto.

It is not liquid, but soft and elastic like gluten of wheat. When first applied to the wood in thin elastic plates, it may be scratched off by the finger, but it soon hardens. It has neither taste nor smell. It is heavier than water. Its fracture is vitreous. It is too tough to be pounded; it can only be rasped down. It becomes electric when rubbed. When heated a little above 212° it becomes elastic like caoutchouc, and rebounds when thrown against a hard body. But it loses its elasticity on cooling. Alcohol separates a little green resin from it, but does not act upon the residue even at a boiling heat. It is insoluble in ether, but swells up and becomes gelatinous. It swells also in fixed oils, but does not dissolve in them. It is insoluble in volatile oils and in water. Sulphuric acid dissolves

* Berzelius, Traité de Chimie, vi. 594.
† Ann. de Chim. et de Phys. lvi. 216.

it, but it is precipitated by water. Potash dissolves it, and converts it into a species of soap, which is soluble in water, and from which it is precipitated by acetic acid exactly similar to the state in which it is used by the Indians at Pasto. It has a silky lustre, and may be drawn out into thin membranes like gluten. In this state it contains water and a little acetic acid. Exposed to the air, it dries, becomes brown, and loses its elasticity. At 266° it melts, and gives out all the water and acetic acid which it contains. After cooling it is brown, very tenacious, and dissolves readily in alcohol, ether, and oil of turpentine. In this state it makes an excellent varnish.

Boussingault analyzed it, and found it composed of

Carbon	70·66 or	10 atoms =	7·5 or	per cent. 71·43
Hydrogen	9·82 or	8 atoms =	1	— — 9·52
Oyxgen	19·52 or	2 atoms =	2	— — 19·05
	100·00		10·5	100·00

It is, therefore, the same in constitution as rosin or copaiva resin, with an additional atom of oxygen.

SECTION XXI.—OF VARNISHES.

The greater number of the resins which have been described in this Chapter are employed in the preparation of varnishes. For this purpose they are dissolved in alcohol, or oil of turpentine, or in a mixture of oil of turpentine and a drying oil. When these solutions are spread upon a surface the solvent evaporates, and leaves the surface covered with a thin coating of the resin employed, which gives a shining appearance to the surface so covered, and at the same time screens it from the action of moisture and of the atmosphere. This covering is what is called, in common language, *a varnish.*

Alcohol varnishes are best made with absolute alcohol. They dry rapidly, and resist even the action of common spirits. Usually they are prepared from alcohol of the specific gravity 0·833. When a powdered resin is put into alcohol it softens, and the particles are agglutinated together, which greatly retards the solution. To obviate this inconvenience, the resin is mixed with about half its weight of pounded glass. This prevents the particles from agglomerating into a mass, or sticking to the bottom of the vessel. It may happen that the varnish, when dry, from the brittleness of the resin employed, may crack, or even fall off in powder when the surface is struck. This is obviated by adding to the varnish a small quantity of Venice turpentine, which gives the coating of varnish a certain tenacity. But this is only a palliative. For the volatile oil of the turpentine gradually evaporates, and leaves the resin as brittle as ever. The best remedy is to add a little linseed oil, either alone, or mixed with oil of turpentine.

Colourless varnish is prepared thus :—Take

6 parts of sandarach
3 parts mastich

1 part elemi
¼ part Venice turpentine
4 parts pounded glass
32 parts alcohol.

When the solution is effected, filter the varnish through paper on a covered funnel. This varnish is hard, and destitute of flexibility.

But the most colourless varnish known is made from copal, steeped in ether till it swells out, and then dissolved in hot alcohol, added by small portions at a time. When copal, which has been previously melted with a little turpentine, is dissolved in absolute alcohol, a varnish is obtained, having a yellow colour. This varnish is very much used, and the yellow colour is concealed by adding a little blue, or by giving a slight tint of blue to the surface before the varnish is applied.

Lac varnish (excepting that it has a brown colour) is the best of all varnishes. To make it, take

8 parts shell lac
4 parts sandarach
1 part Venice turpentine
4 parts pounded glass
60 parts alcohol.

This is the varnish applied over brass ornaments, and technically called lacker. The surface of the brass is made quite clean, by steeping it in a weak solution of nitric acid. It is then washed in hot water, dried speedily in bran, and covered instantly with hot varnish. This prevents the action of the air, which tarnishes brass with great rapidity.

Oil of turpentine varnishes, like those of spirit of wine, are either colourless or coloured. A colourless varnish is made thus:—

24 parts mastich
3 parts Venice turpentine
1 part camphor
10 parts pounded glass
72 parts oil of turpentine.

This is the varnish usually employed to cover oil paintings, maps, and engravings. The paper ought first to be covered with a thin coating of isinglass, which prevents the varnish from passing through the paper and rendering it transparent.

Several processes for making copal varnishes have been given in a preceding Section of this Chapter, when treating of copal. To that Section the reader is referred for information on the subject.

Both alcohol and turpentine varnishes may be coloured. *Yellow* by turmeric, anotta, saffron, gamboge. *Red* by dragon's blood, cochineal, red sanders, safflower, orcanette. *Green* by acetate of copper, or resinate of copper. All the opaque colours may be obtained by levigating the respective colouring matters, and mixing them in that state intimately with the varnish. In this way, cin-

nabar, indigo, Prussian blue, chromate of lead, &c., may be mixed with varnishes to communicate their respective colours.

The following is the receipt for making a gold coloured varnish :—

8 parts shell lac
8 parts sandarach
4 parts Venice turpentine
1 part dragon's blood
$\frac{1}{4}$ part turmeric
$\frac{1}{4}$ part gamboge
64 parts oil of turpentine.

A similar varnish, having alcohol for its vehicle, is formed of the following ingredients :—

4 parts shell lac
4 parts sandarach
4 parts elemi
1 part dragon's blood
192 parts alcohol of 0·85.

The varnish made in this way is red, and requires, before having the golden colour, to be mixed with a yellow colouring matter. For this purpose a similar varnish to the preceding is made, only substituting gamboge for dragon's blood. These two varnishes are mixed in the proportions found by trial best for giving the varnish a golden colour.

Brass may be made to assume a golden colour, by corroding its surface for some minutes by means of a mixture of 6 parts nitric acid free from muriatic acid, and 1 part of sulphuric acid; then, it is to be washed and put into a saturated solution of bitartrate of potash. Finally, it is dried, by rubbing it in saw-dust. The varnish is now applied with a pencil, and dried by the application of heat.

When wood is varnished, the varnish requires to be polished, in order to give the surface the requisite lustre. For this several coats of varnish are applied in succession, taking care that those first applied are dry before a new one be laid on. After being allowed to dry for some days, the surface is rubbed with tripoli and oil, and when the surface is quite smooth, the polish is finished by rubbing the varnish with fine starch till it has acquired the requisite brilliancy.

When rosewood tables are varnished, they are first polished with pumice, and then with tripoli and linseed oil. The whole is then rubbed over with lac varnish, mixed with a very little linseed oil. During the rubbing the varnish dries, and acquires polish.*

* Berzelius, Traité de Chimie, v. 533.

CHAPTER X.

OF GUM RESINS.

THERE are many plants which, when cut or pierced, give out a milky juice, more or less thick. It has generally a strong taste, and frequently also a peculiar smell. These milky juices are contained in the living plant, in a peculiar set of vessels which usually run along the interior part of the bark. The common *leontodon taraxicum*, *lactuca virosa*, the different species of *euphorbia*, the *poppy*, &c., may be mentioned as examples of plants yielding these milky juices. When the milky juice is made to exude from a plant, and then exposed to the atmosphere, it becomes solid, and assumes different appearances according to the plant from which it is obtained. Now, these concrete juices are the substances which have long been distinguished by the name of *gum resins*. Several of them have been introduced into medicine, and act with considerable energy when taken into the stomach. On that account, though they contain no peculiar principle, but consist of gums, resins, oils, starch, &c., in various proportions, it will be proper to give an account of the most important of them here.*

The gum resins are usually opaque, or at least their transparency is inferior to that of resins. They are always solid, and most commonly brittle, and have sometimes a fatty appearance.

When heated they do not melt as the resins do; neither are they so combustible. Heat, however, commonly softens them, and causes them to swell. They burn with a flame.

They have almost always a strong smell, which in several instances is alliaceous. Their taste also is often acrid, and always much stronger than that of the resins.

They are partially soluble in water; but the solution is always opaque, and usually milky.

Alcohol dissolves only a portion of them. The solution is transparent; but when diluted with water it becomes milky; yet no precipitate falls, nor is any thing obtained by filtering the solution.

They dissolve much better in dilute alcohol, which takes up the gum, resin, and extractive matter which they may contain.

Mr Hatchett found them all soluble in the caustic alkalies, and this has been confirmed by subsequent experimenters. The dilute alkalies dissolve them completely, leaving nothing but foreign matter.

They dissolve better in acid, and especially in concentrated acids,

* The gum resins first make their appearance as a peculiar class of vegetable substances in Neumann's Chemistry.

than in water; but in general the mineral acids decompose them. From the experiments of Mr Hatchett, we learn that sulphuric acid dissolves them, and gradually converts them into artificial tannin and charcoal. The following are the quantities of charcoal obtained by this chemist from 100 grains of gum resins digested in alcohol:—

Ammoniac	58
Asafœtida	51
Olibanum	44
Myrrh	40
Gamboge	31

Nitric acid acts upon them with energy; converting them first into a brittle mass, and then, with the assistance of heat, dissolving them. By evaporating this solution, Mr Hatchett obtained, from ammoniac and asafœtida, a portion of artificial tannin; but he did not succeed in procuring it by the same means from olibanum, myrrh, and gamboge.*

Their specific gravity is usually greater than that of the resins.

The gum resins, in a medical point of view, may be divided into four sets; namely,

1 The fetid gum resins
2 The stimulating
3 The cathartic
4 The sedative.

In this Chapter we shall take a view of the most important gum resins belonging to each of these Divisions.

DIVISION I.—OF FETID GUM RESINS.

These gum resins have an alliaceous, or at least a peculiar smell, and have a good deal of resemblance to fatty matter. The principal fetid gum resins are the five following:—

1 Ammoniac
2 Galbanum
3 Asafœtida
4 Opoponax
5 Sagapenum

SECTION I.—OF AMMONIAC.

The plant which yields this gum resin is a native of the north of Persia. It was brought lately to England by Colonel Wright, and has been described by Mr David Don, under the name of *Dorema ammoniacum*.† It had been previously conjectured by Willdenow that it was the produce of the *Heracleum gummifera*. He made the seeds vegetate, which are occasionally met with in ammoniac, and constituted the plant which spring from them into a new species

* Phil. Trans. 1806.

† Philosophical Magazine (New Series), ix. 47. Mr Don considers *ammoniac* to be a corruption of *armeniacum*, indicating the country (Armenia) whence the gum came.

under that name. But as this plant was not observed to yield ammoniac, Willdenow was not able to establish his opinion.*

Ammoniac is imported in small pieces agglutinated together, and has a yellowish-white colour. Its smell is somewhat like that of galbanum, but more pleasant. Its taste is a nauseous sweet, mixed with bitter. It does not melt. Water dissolves a portion of it; the solution is milky, but gradually lets fall a resinous portion. More than one-half is soluble in alcohol. This portion is a resin. Colour white, soft, and ductile. Melts when heated, and burns like a resin. When heated becomes harder, but not brittle. Nearly tasteless. Soluble in ether and in nitric acid. Precipitated from it in the form of an orange substance, partly resin, partly bitter. A portion remains, and gives the liquid a yellow colour. Taste of the solution slightly acid and bitter. Not precipitated by carbonate of soda, ammonia, nitrate of silver, nor acetate of lead. The orange substance has a bitter taste. When heated, readily swells and blackens, but does not flame. Burns without leaving any residuum. Lighter than water. When agitated in water, tinges it yellow, but does not all dissolve. The specific gravity of ammoniac is 1·207. Mr Hatchett found it soluble in alkalies. Neither alcohol nor water, when distilled off it, bring over any thing.

According to the analysis of Braconnot, ammoniac is composed of the following ingredients:—

Resin	70·0
Gum	18·4
Glutinous matter . . .	4·4
Water	6·0
Loss	1·2
	100·0

The resin he found brittle and yellow. In these respects it differs from the resin which I extracted from ammoniac, which was soft, and continued so after being exposed to the air for two months. This difference is probably owing to the state of the ammoniac; sometimes it is brittle and yellow, at other times soft and white. It was in this last state that I examined it. Braconnot found the yellow matter into which this resin is converted by nitric acid soluble in hot alcohol and water. It had the property of dyeing silk a fine yellow colour, not altered by chlorine. The gum which he extracted from ammoniac possessed the properties of common gum, as far as he examined them. It is transparent, yellowish, brittle, soluble in water, and precipitated by subacetate of lead, but not by the acetate, nor the nitrate of lead. The mercurial salts render the solution milky. By nitric acid it is converted into saclactic and oxalic acids, and furnishes also a little malic acid. The glutinous matter was insoluble in water and alcohol; it became black when

* See Ann. de Chim. lxix. 267.

dried, and yielded a yellow matter and some oxalic acid when treated with nitric acid.*

Ammoniac is an antispasmodic, but undoubtedly the least powerful of all the fetid gum resins. It is occasionally administered as an expectorant; but in this country at least, its expectorant powers are not much confided in. It is said to act as a purgative when administered in large doses. It is sometimes used as an external application, in cases of white swelling of the knee joint, &c.

SECTION II.—OF GALBANUM.

Mr David Don has lately advanced sufficient reasons for thinking that this gum resin is the product of a plant allied to the genus *Siler*. He proposes to call it *Galbanum officinale*. It is a native of Persia. It has been generally considered as the product of the *Bubon Galbanum*, an umbelliferous plant, which grows in Africa, Arabia, and Syria.†

Galbanum comes to this country from the Levant, in small pieces composed of tears, agglutinated together, of a yellowish or white colour. The best is in ductile masses, composed of distinct whitish tears, agglutinated together by a pale-brown or yellowish substance. The separate tears constitute the best part of the mass. When the colour is dark-brown or blackish, it must be rejected as bad.

Its taste is acrid and bitter, and its smell peculiar. Water, vinegar, and wine dissolve part of it, but the solution is milky. Alcohol dissolves about $\frac{3}{5}$ths. When distilled it yields about half its weight of volatile oil, which has at first a blue colour. Its specific gravity is 1·212.‡

According to the analysis of M. Meisner, it is composed as follows:—

Resin	65·8
Gum	22·6
Cerasin	1·8
Malic acid	0·2
Volatile oil	3·4
Vegetable debris	2·8
Loss	3·4
	100·0§

Besides these substances, traces of malates were found. When galbanum is distilled, it yields acetic acid held in solution by water, then an oil, at first green, then blue, and lastly, reddish-brown.

The volatile oil contained in galbanum is colourless and limpid. Its specific gravity is 0·92. Its odour resembles at once that of galbanum and of camphor. Its taste is at first hot, then cooling and bitter. It dissolves easily in alcohol, ether, and the fixed oils.

* Ann. de Chim. lxviii. 69.
† Woodville's Medical Botany, i. 98.
‡ Brisson. § Annals of Philosophy, xiv. 385.

The resin of galbanum is dark brownish-yellow, translucent, brittle, and tasteless. It is insoluble in spirits, but very soluble in absolute alcohol, in ether, and in almond oil. Oil of turpentine dissolves very little of it, even when assisted by heat. Concentrated sulphuric acid dissolves it readily. Hot nitric acid destroys it, the smell of acetic acid is perceptible, oxalic acid is formed, and there remains a yellow, bitter, brittle substance, which does not melt when heated, but undergoes decomposition, giving out a peculiar odour. When this resin is digested with hydrate of potash, a combination is formed, which is insoluble in water.*

The medicinal properties of galbanum are considered as of the same kind with those of ammoniac; but it acts with more energy, though with less than asafœtida. It has been found useful in hysteria; and has been occasionally administered in chlorosis, asthma, and chronic rheumatism. It is usually given in pills to the extent of from 10 grains to half a dram. It is also used as an external application.

SECTION III.—OF ASAFŒTIDA.

This gum resin is obtained from the *ferula asafœtida*, a perennial plant, which is a native of Persia. When the plant is about four years old, its roots are dug up and cleaned. Their extremity being then cut off, a milky juice exudes, which is collected. Then another portion is cut off, and more juice exudes. This is continued till the roots are exhausted. The juice thus collected soon hardens and constitutes *asafœtida*. It comes to Europe in small grains of different colours, whitish, reddish, violet, brown. Pretty hard, but brittle. Its taste is acrid and bitter; its smell strongly alliaceous and fetid. Alcohol, according to Neumann, dissolves about $\frac{3}{4}$ths of this substance; and water takes up nearly $\frac{1}{4}$th, if applied before the spirit. A considerable portion of earthy matter remains undissolved. It yields a volatile oil, both when distilled with water and alcohol. This oil possesses the active properties of the asafœtida itself.† The specific gravity of the gum resin is 1·327.

According to the analysis of Brandes, asafœtida is composed of

Volatile oil	9·6
Resin	48·85
Gum, with traces of potash and lime combined, sulphuric, phosphoric, acetic, and malic acids	19·40
Mucilage	6·4
Extractive, with malate of potash	1·4
Sulphate of lime, with traces of phosphate	6·2
Peroxide of iron and alumina	0·4
Impurities	4·6
	96·85

* Berzelius, Traité de Chimie, vi. 144. † Neumann's Chemistry, p. 312.

It is to the *volatile oil* that this gum resin owes its disagreeable smell. This oil is lighter than water, very volatile, colourless and limpid when fresh, but by keeping it acquires a yellow colour. Its taste is bitter and rather acrid. It is said to be soluble in 2000 times its weight of water; but alcohol and ether dissolve it in all proportions. According to Zeise, it contains sulphur as a constituent. It probably, therefore, belongs to the same division of oils with oil of mustard, the nature and properties of which were described in a former Chapter of this work.

When the *resin* of asafœtida is digested in ether, it is divided into two different resins, one of which, amounting to $\frac{1}{6}$th of the weight of the gum resin, is insoluble in ether, very soluble in alcohol, alkalies, oil of turpentine, and oil of almonds. It has a deep yellow colour, is brittle, tasteless, and easily fused.

The other resin, which dissolves readily in ether, has a deep greenish-brown colour, is brittle, and breaks with a conchoidal fracture. It has an aromatic smell, and its taste is feeble, but similar to that of garlic, and it remains long in the mouth. When heated, it melts, and gives out a disagreeable smell. It is very soluble both in absolute and dilute alcohol, and likewise in ether, and oil of turpentine, and oil of almonds. Chlorine renders it white. Sulphuric acid dissolves it, and water throws it down from this solution. When the solution is heated, sulphurous acid is given off. When we now dilute it with water, and neutralize the acid by an alkali, the surface assumes a sky-blue colour. Nitric acid communicates an orange colour, which gradually passes into sulphur-yellow, rendering it bitter, and slightly soluble in water; but insoluble in ether, and in the fixed and volatile oils. By the continued action of nitric acid, oxalic acid is formed; and, according to Brandes, mucic acid also.

This resin combines with muriatic acid, losing at the same time its greenish colour, and the property of dissolving in weak alcohol. It becomes acid, and now only dissolves in absolute alcohol at a boiling temperature.

It dissolves by boiling in concentrated acetic acid, and is again deposited when the solution cools.

This gum resin is a good deal employed in medicine as an antispasmodic, especially in cases of hysteria. It is also administered as an expectorant in asthma and hooping-cough; and it has been long a favourite remedy in chlorosis. The dose is from 5 grains to 20, and it is most commonly given under the form of pills; though sometimes diffused in water.

SECTION IV.—OF OPOPONAX.

This substance is obtained from the *pastinaca opoponax*, a plant which is a native of the countries round the Levant. The gum resin, like most others, is obtained by wounding the roots of the plant. The milky juice, when dried in the sun, constitutes the opoponax. It is in lumps of a reddish-yellow colour, and white

within. Smell peculiar. Taste bitter and acrid. With water it forms a milky solution, and about one-half of it dissolves. Alcohol acts but feebly. When distilled with water or alcohol, these liquids acquire the flavour of opoponax, but no oil separates.* Its specific gravity is 1·622.†

When distilled it yields a brown oil, acetic acid, in which a bituminous oil swims, the residual charcoal weighs $\frac{28}{100}$ of the opoponax distilled. When incinerated it left $\frac{37}{280}$ of its weight of ashes, composed of

Carbonate of lime . . .	18
Silica	2
Carbonate, Sulphate, Muriate of potash . .	15
	35

According to the analysis of Pelletier, to whom we are indebted for the preceding distillation, opoponax is composed of the following constituents:—

Resin	42·0
Gum	33·4
Wood	9·8
Starch	4·2
Malic acid	2·8
Extractive	1·6
Caoutchouc	Trace
Wax	0·3
Volatile oil and loss . . .	5·9
	100·0‡

Opoponax was formerly employed in medicine, and considered as possessed of virtues similar to those of asafœtida. But at present it is very rarely used in Great Britain.

SECTION V.—OF SAGAPENUM.

This gum resin is brought to this country from Smyrna, Aleppo, and Alexandria, and is supposed to be the produce of the *ferula persica*, a plant which Dr Hope described as the plant which yields asafœtida. If it be the sagapenum (σαγαπηνον) of Dioscorides, it was brought in his time from Media.

It is commonly in tears agglutinated together. Colour yellow. Taste hot and bitter. Smell alliaceous. Softens between the fingers, but does not melt when heated. Sparingly soluble in water, but almost completely soluble in alcohol. When distilled with water it yields a little volatile oil. The water is strongly impregnated with the flavour of the sagapenum.§ When distilled with water it gives a volatile oil. It was analyzed by Brandes, who found it composed of

* Neumann's Chem. p. 316. † Brisson.
‡ Ann. de Chim. lxix. 90. § Neumann's Chem. p. 316.

Volatile oil . .	3·73
Resin	50·29
Gum, with potash and some salts	32·72
Mucilage	4·48
Malate and sulphate of lime .	0·85
Phosphate of lime . . .	0·27
Foreign matters . . .	4·30
Moisture	4·60
	101·24

The volatile oil is pale yellow, very fluid, and lighter than water, has a very disagreeable alliaceous smell, and a bitter acrid taste somewhat like that of onions. It appears to contain a more volatile oil with an odour of onions, and having a taste at once analogous to that of turpentine and camphor. When the volatile oil of Sagapenum is exposed to the air, it is speedily changed into a transparent resin. It dissolves readily in alcohol and ether.

The *resin* of sagapenum is decomposed by ether into two resins. The one, insoluble in ether, is yellowish-brown, brittle, insipid, and destitute of odour. When heated, it swells up and fuses. It is very soluble in alcohol. Oil of turpentine and oil of almonds do not dissolve it, even when assisted by heat. It dissolves readily in caustic potash, but not in ammonia. It constitutes about 2·38 per cent. of the sagapenum.

The other *resin* dissolves in alcohol and ether. It has a reddish-yellow colour, is transparent and soft; but when long kept it becomes hard. It has the same odour as sagapenum, and a bitter and disagreeable taste. When heated it melts, swells, and catches fire. It is but little soluble in oil of turpentine and oil of almonds. When put into hot chlorine water, it assumes a green and a blue colour. Sulphuric acid dissolves it, assuming a deep red colour. When we pour water into the solution, a deep violet substance swims on the surface, and the liquid becomes red. Boiling nitric acid partly dissolves it, oxalic acid being formed, while a yellow brittle bitter-tasted resinous matter remains behind.

This resin is slightly soluble in water, very soluble in alcohol, oils of turpentine and almonds; but insoluble in ether. When heated it melts and swells up. When ammonia is poured into the nitric acid solution, a yellow-coloured flocky precipitate falls, soluble with a red colour, in an excess of ammonia.

When muriatic acid is digested with the *resin b* of sagapenum, it becomes first pale red, then violet, then blue, and by boiling, reddish-brown. Alkalies precipitate nothing from this solution.

Sagapenum is conceived to possess similar medicinal qualities with ammoniac and asafœtida. But it is not so powerful as the last of these, and is therefore very little used, at least in this country.

DIVISION II.—OF STIMULATING GUM RESINS.

The term *stimulating*, which I have applied to this class of gum resins, is not very proper, as the fetid and the cathartic gum resins undoubtedly possess stimulating properties to a greater extent than *olibanum*, *myrrh*, *euphorbium*, and *bdellium*, the four gum resins which I propose now to describe; but I cannot think of any other term which would characterize them better.

SECTION I.—OF OLIBANUM.

This substance is the fankincense of the ancients. They obtained it, as Dioscorides informs us, from Arabia and India. From Pliny we learn that the tree which yielded it was neither known to the Greeks nor Romans. At present olibanum is imported to London in chests, containing each about a hundred weight. It comes from different places, among others from the East Indies, but the Indian olibanum is least esteemed. The tree which yields this gum resin continues still doubtful. The probability is, that different species of trees furnish it in different countries. Lamark is of opinion that the tree which yields the Arabian olibanum is the *amyris gileadensis*. It is called by the natives *soukiou*. According to Foerskal, it is the *amyris kataf*. Mr Colebrook has shown that the Indian olibanum comes from the *boswellia serrata* of Roxburgh, a large tree, which grows on the mountains of India.*

Olibanum is a semitransparent, brittle, whitish-yellow substance, usually covered externally by a whitish farinaceous substance, produced by the pieces rubbing against each other. Its taste is acrid and aromatic, and when burnt, it diffuses an agreeable odour. When heated, it melts with difficulty, but burns brilliantly, and leaves a whitish ash composed of phosphate of lime, carbonate of lime, and sulphate, muriate and carbonate of potash. According to the analysis of Braconnot, it is composed of the following constituents:—

Volatile oil	8
Resin	56
Gum	30
Matter like gum, insoluble in water and alcohol	5·2
Loss	0·8
	100·0†

The oil had a lemon colour, and a smell similar to the oil of lemons.

The resin is reddish-yellow, brittle, tasteless, and very similar in appearance to rosin. Boiling water softens it; but a higher temperature is necessary to melt it. When burnt, it emits rather an agreeable odour. When heated to dryness with potash ley, it leaves a matter which is capable of forming a kind of emulsion with boiling water.

The gum possesses few peculiarities. The infusion of nut-galls

* Asiatic Researches, ix. 377. † Ann. de Chim. lxviii. 60.

occasions a precipitate in its aqueous solution. Nitric acid converts it partly into saclactic acid.*

Olibanum possesses stimulating qualities, and was formerly much used as a vulnerary, and in gleets, and affections of the chest. But at present it is hardly ever used for any other purpose than as a perfume.

SECTION II.—OF MYRRH.

Mr Bruce endeavoured to prove that the plant which yields this gum resin is a species of *Mimosa*;† but this evidence is not very satisfactory; though he has shown that our myrrh is the same as that of the ancients. It was said to be obtained by incisions from the *amyris kataf.* Ehrenberg and Hemprich have at last ascertained, that the real tree which yields this drug is the *balsamodendron myrrha*, which grows in Arabia and Abyssinia; and Humboldt assures us, that this is the same plant with the *amyris kataf* of Foerskal.‡ The Abyssinian myrrh comes to this country from the East Indies. It is said by Mr Bruce to be by far the best in point of quality. The Arabian comes by way of Turkey.

It exudes from the tree in the state of a yellowish-white liquid, which soon concretes into a solid substance. The best myrrh is transparent, and has a reddish-brown colour. It is brittle, and exhibits tortuous veins of a lighter shade. It is often opaque. Odour peculiar. Taste bitter and aromatic. Does not melt when heated, and burns with difficulty. With water it forms a yellow opaque solution. The solution in alcohol becomes opaque when mixed with water, but no precipitate appears. By distillation with water it yields an oil heavier than water; but nothing comes over with alcohol.§ Its specific gravity is 1·360.‖ Mr Hatchett found it soluble in alkalies.

From the analysis of Braconnot, it appears that myrrh is composed of

Volatile oil	2·5
Resin	23·0
Gum	46·0
Mucilage	12
	83·5

Brandes states its composition as follows:—

Volatile oil	2·6
Resin	27·8
Gum	54·4
Mucilage	9·3
Salts¶	1·4
Foreign bodies	1·6
	97·1

* Braconnot, Ann. de Chim. lxviii. 60.
† Phil. Trans. 1775, p. 408.
‡ See Jour. de Pharmacie, xv. 69.
§ Lewis, Neumann's Chem. p. 317.
‖ Brisson.
¶ Sulphates, benzoates, malates, and acetates of potash and lime.

The *volatile oil* contained in myrrh is colourless; but when long kept, acquires a shade of yellow. It is very fluid, has the smell of myrrh, and a balsamic and camphoric taste. When exposed to the air it thickens into a varnish. It cannot be distilled over with spirit of wine. Alcohol, ether, and the fixed oils dissolve it readily. It combines with sulphuric, nitric, and muriatic acids, forming a red coloured liquor, which becomes muddy when mixed with water. When the ethereal solution of this oil is shaken with muriatic acid, the acid takes most of the oil from the ether, and forms with it a red liquid, which sinks to the bottom of the glass.

The *resin*, when treated with ether, is decomposed into two resins, one soluble, the other insoluble in that liquid.

The ether dissolves a quantity of resin, amounting to 5·56 per cent. of the myrrh originally employed. This resin is soft, at the ordinary temperature of the air; but hardens by degrees. Its taste is at first slight, but it becomes very bitter and acrid. When heated it melts and swells up. It dissolves readily in alcohol, ether, and oil of turpentine; less easily in oil of almonds. With ammonia it forms a muddy solution.

The *resin* insoluble in ether amounts to 22·24 per cent. of the weight of the myrrh. It has a yellowish-brown colour, is translucent, hard, and brittle. It melts when exposed to the action of heat. It has neither taste nor smell, and softens like wax when kept in the mouth. Alcohol dissolves it easily. It is less soluble in oil of turpentine, still less in oil of almonds, and not at all in ether. The caustic alkalies, ammonia included, dissolve it easily. It forms with barytes a resinate soluble in water, but insoluble in alcohol.

The *gum* remains, after the extraction of the resin by alcohol, under the form of a greyish-white powder, seemingly insipid at first, but becoming aromatic. Water dissolves it into a liquid more mucilaginous than that formed by an equal quantity of gum arabic. This solution is precipitated white by alcohol, hydrate of potash, and the salts of tin, lead, mercury, and silver. Nitric acid decomposes this gum with much violence, and transforms it into oxalhydric and oxalic acids, and into a bitter matter, which does not detonate. Not the smallest particle of mucic acid is formed. When this gum is distilled, much acetate of ammonia is formed.

Myrrh, in a medicinal point of view, is considered as a tonic and expectorant. The alcoholic solution of it, under the name of tincture of myrrh, is much used as a dentifrice. At one time it was a favourite remedy in ulcers of the lungs. It is administered in the form of pills, of tincture, and of watery infusion.

SECTION III.—OF EUPHORBIUM.

This gum resin is obtained by incisions from the *euphorbia officinalis*, and it is said also from the *euphorbia antiquarum* and *caneriensis*, plants which grow in the interior of Africa. The *euphorbia officinalis* is a shrubby plant, about 5 feet in height. It seems

to be the plant described and figured by Bruce, under the name of *Kol-Quall*, and which Jackson, in his account of Morocco, says the Arabs and Shellahs call *Dergmuse*. Mr Jackson informs us, that in the lower regions of Mount Atlas, the inhabitants collect the concrete gum resin, which they call *furbiune*, in September. It is obtained by making slight incisions in the branches of the plant with a knife, from which a milky juice exudes, which concretes into tears of an oblong or roundish form. The quantity obtained is so considerable, that the plants are cut only once in four years. The milky juice is so corrosive as to erode the skin wherever it touches.

It comes to this country in large irregular pieces, often pierced with holes, externally of a dirty-yellow or reddish colour, internally white. It is solid, easily pulverized, and destitute of smell, and appears at first insipid, but leaves an acrid impression in the mouth, and occasions inflammation of the mouth and throat. Indeed, euphorbium is so acrid, that unless those who pound it use great precautions to prevent the powder from coming in contact with the face, the nose, eyes, and indeed the whole face is inflamed.

We have four analyses of this gum resin. The following table exhibits the results obtained :—

	Laudet.	Braconnot.	Pelletier.	Brandes.
Resin	64·0	37·0	60·8	43·77
Wax	—	19·0	14·4	14·93
Caoutchouc . . .	—	—	—	4·84
Gum	23·3	—	—	—
Malate of potash . .	—	2·0	1·8	4·90
Malate of lime . .	—	20·5	12·2	18·82
Bussarin . . .	—	—	2·0	—
Lignin	9·3	13·5	—	5·60
Sulphate of potash .	—	—	—	0·45
Sulphate of lime . .	—	—	—	0·10
Phosphate of lime . .	—	—	—	0·15
Water	—	5·0	8·0	5·40
	96·6	97·0	99·2	98·96

Besides water, Pelletier found a volatile oil; and, according to Brandes, the wax is composed of 13·7 cerin, and 1·23 myricin. What Laudet calls gum, is doubtless the malate of lime and of potash, discovered by the other analysts. It seems established that euphorbium contains no gum whatever.

The *resin* constitutes the important constituent of euphorbium. It is reddish-brown, translucent, brittle, and soft enough to be scratched by the nail. Its smell is sweetish, its taste caustic. When heated it melts, and then chars, without swelling, but giving out the odour of benzoin. Alcohol dissolves it easily, and it may be dissolved in the fixed oils. Concentrated sulphuric acid dissolves it, and water throws it down from that solution. Cold nitric acid

transforms it into a yellow bitter substance insoluble in water, but soluble in alcohol. When heat is applied, the resin dissolves in nitric acid; but it precipitates again when the solution cools. Traces of oxalic acid can be detected, and likewise mucic acid, according to Brandes.

Cold muriatic acid does not attack this resin; but when at the boiling temperature, it dissolves a small portion. The resin dissolves with difficulty in caustic potash, and partly precipitates when the solution is diluted with water. It is also slightly soluble in ammonia. This resin is poisonous, and blisters the skin when applied to it.

This resin was subjected to a chemical analysis by H. Rose. He obtained

Carbon	81·58 or	10 atoms	= 7·5	or per cent.	83·33
Hydrogen	11·35 or	8 atoms	= 1·0	— —	11·11
Oxygen	7·07 or	½ atom	= 0·5	— —	5·56
	100·00*		9		100·00

But	15 atoms carbon	= 11·25	or per cent.	81·08
	12 atoms hydrogen	= 1·625	— —	11·71
	1 atom oxygen	= 1·00	— —	7·21
		13·875		100

would approach much nearer to the result of the analysis.

Euphorbium was formerly used as an internal medicine; but its effects were so violent, that it has been laid aside in this country. As an errhine, it can hardly be used alone, because it occasions so much inflammation as to produce hæmorrhage from the nostrils. But when sufficiently diluted with starch, it may be used without injury, and answers the purpose perfectly. Applied externally, it acts as a rubefacient, or even as a vesicant; but it is very seldom had recourse to in this country.

SECTION IV.—OF BDELLIUM.

This gum resin comes to us from the Levant. The shrub which yields it is a native of Senegal, and has been recently described by Guillemin, under the name of *Heudelotia africana*.† It had been supposed by some to be the *borassus flabelliformis*; by others the *Chamærops humilis*, but the most general opinion was, that it was a species of *amyris*.

Bdellium is in little translucent angular masses, of a reddish colour, and shining in the fracture. It has a weak, but disagreeable smell, and its taste is nauseous, having some analogy to turpentine. When triturated between the teeth it becomes soft. When thrown upon burning coals it becomes soft, and burns like a resin. Its specific gravity is 1·371.‡ Alcohol dissolves about $\frac{3}{5}$ths of its weight of bdellium, the undissolved portion is a mixture of gum and cerasin. According to the analysis of Pelletier, its constituents are:—

* Poggendorf's Annalen, xxxiii. 52. † Jour. de Pharmacie, xix. 312.

‡ Brisson.

Resin	59
Gum	9·2
Mucilage	30·6
Volatile oil and loss . .	1·2
	100·0*

The *volatile oil* is heavier than water. The *resin* is transparent, but when boiled with water it becomes white and opaque. It melts when heated to about 140°. The *gum* has a yellowish-grey colour, and gives, when treated with nitric acid, oxalic acid and traces of mucic acid. The *mucilage* undergoes the same alteration from nitric acid as the gum. Water dissolves it into a mucilaginous liquid, which is coagulated by alcohol, and rendered liquid by nitric acid.

DIVISION III.—OF CATHARTIC GUM RESINS.

The gum resins belonging to this class are drastic purgatives, one of which at least, *aloes*, is in common use in this country.

SECTION I.—OF ALOES.

Strictly speaking, *aloes* hardly belongs to the gum resins. However, as it often exudes spontaneously from the leaves, when the point of them is cut off, and afterwards gradually concretes into a solid mass, the analogy is so close, that I am not aware of any other set of vegetable principles to which it bears a nearer relation.

Two kinds of *aloes* occur in commerce, *Socotrine aloes* and *Barbadoes aloes*. The first kind came originally from Zocotora, an island at the entrance of the Red sea; but of late years, this country is almost entirely supplied with aloes from Bombay. The plant which yields this variety is the *aloe spicata*. The leaves are cut off close to the stem, then cut in pieces and the juice allowed to run out. This liquid is left at rest for 24 hours, during which a feculent matter is deposited. The clear liquid is now drawn off and left to concrete in the sun. The Barbadoes aloes is the product of the *aloe vulgaris*, which Dr Sybthorp considers as the aloe (Αλοη) of Dioscorides.

The month of March is the time for cutting the aloes in the island of Barbadoes. The leaves are cut off close to the stem and deposited in tubs, so that the juice may run out. When a sufficient quantity is collected, it is heated in copper boilers, and as it becomes more inspissated, it is ladled from one boiler to another and fresh juice added. When of the consistence of honey, it is poured into calabashes, where it hardens by age. Barbadoes aloes is considered as inferior to Socotrine aloes, though it is suspected that they are often substituted for the more valuable variety.

Aloes has a reddish-brown colour. It is solid, but softens in the hand and becomes adhesive. Its taste is intensely bitter. Barbadoes aloes has a stronger and more unpleasant smell than Socotrine

* Ann. de Chim. lxxx. 39.

aloes. It dissolves for the most part in water and alcohol. Water leaves undissolved a brown substance, which is partially soluble in boiling water, but is again deposited when the liquid cools. This substance agglomerates into a soft mass, fusible by heat, and very soluble in alcohol, ether, and the alkalies. This substance was considered as a resin; but it appears from the experiments of Braconnot, that it is nothing else than what used to be called *oxydized extractive*, and to which Berzelius has given the name of *apotheme*,* mixed with a little unaltered aloes. This last substance may be separated by digesting the whole with oxide of lead mixed with water. The oxide combines with the apotheme, which remains behind, while the other matter is dissolved in the water. By digesting in very dilute nitric acid, the oxide of lead is dissolved, and the apotheme remains under the form of a brown powder.

It is insoluble in cold water, gives a yellowish-brown colour to boiling water, dissolves with difficulty in alcohol, and is precipitated from that solution by the addition of water. And when the alcohol is evaporated, the apotheme remains unaltered. It is soluble in the alkalies, and precipitated from this solution by the acids, and the precipitate which falls contains an acid in combination. It burns like tinder, without flame, and without melting.

The portion of aloes which dissolves in water, has received the name of *bitter principle* of aloes. When the solution is left to itself for some months, it becomes clammy, and may be drawn into threads, but it neither putrefies nor deposits mucus. In that state, it is copiously precipitated by infusion of nutgalls. The *bitter principle* of aloes, is soluble in weak alcohol, but not in absolute alcohol, nor in ether. Chlorine passes through its solution, causes a coagulum to fall analogous to the portion of aloes not soluble in water. Cold sulphuric acid dissolves it without alteration. Cold nitric acid dissolves it, assuming at the same time a green colour. When heat is applied to this solution, oxalhydric and oxalic acids are formed, and a reddish resinous substance, having the smell of Vanilla, and detonating when gently heated.

The bitter principle of aloes, dissolved in water, becomes lighter coloured when an acid is added, while a slight precipitate falls. The alkalies, and the salts of peroxide of iron, give the solution a deep-red colour. Protochloride of tin throws down a slight precipitate. The acetate of lead, tartar emetic, salts of manganese, of zinc and of copper, produce no sensible effect. Nitrates of mercury and silver, occasion a precipitate which does not appear till some time after the mixture has been made.

Aloes is very much used in medicine. It is an active and brisk purgative, when given in such a way that it may enter into solution in the stomach. But it is usually administered in pills, which make their way into the larger intestines, before they are broken up. This is probably the reason why aloes is commonly supposed to have a peculiar action on the rectum.

* Traité de Chimie, v. 548.

SECTION II.—OF SCAMMONY.

This gum resin is obtained from the *convolvulus scammonia*, a climbing plant which grows in Syria, and was first correctly described by Dr Russel.*

Scammony is obtained from the root of the plant, which alone contains it, and is collected in the beginning of June, in the following manner:—The ground is cleared away from the root, the top of which is then cut off in a sloping direction, about two inches below the place whence the stalks spring. The milky juice which flows out, is collected in a shell placed conveniently for the purpose. Each root yields a few drachms only, which are drained off in about twelve hours. The juice from the several roots is put together, often into the leg of an old boot, for want of a more proper vessel, where, in a little time it hardens, and constitutes scammony.†

It comes to this country from the Levant, in large soft and porous masses, having rather a brilliant fracture. It is brittle, easily reduced to powder, and has a disagreeable smell, and a nauseous, bitter, and acrid taste. The powder of it is greyish-white. By the action of heat, it may be entirely melted, and when boiled with water, after being reduced to powder, it again coheres into a mass. Water digested on it becomes milky, and assumes a greenish colour.

Smyrna scammony is inferior to that of Aleppo, and is said to be obtained by evaporating the expressed juice of the plant. Alcohol dissolves the greatest part of it. It is usually mixed with impurities, which alter its appearance. Its specific gravity is 1·235.‡

Vogel and Bouillon La Grange have analyzed the two varieties of scammony that come from Aleppo and from Smyrna. The scammony of Aleppo was composed of

Resin	60
Gum	3
Extractive	2
Vegetable debris, earth, &c	35
	100

The scammony of Smyrna was composed of

Resin	29
Gum	8
Extractive	5
Vegetable debris, &c.	58
	100§

The resin of scammony is yellow, translucent, brittle, and very soluble in alcohol. That from Smyrna scammony is brown, transparent, difficult to pound, and its alcoholic solution is deeper than that of the resin from Aleppo scammony. From some trials stated in the *Journal de Pharmacie* (xiii. 589), it appears that the resin of

* See an abridgement of his account by Dr Lewis, Neumann's Chem. p. 303.
† Russel's Aleppo, ii. 246. ‡ Brisson. § Ann. de Chim. lxxii. 61.

scammony may be rendered colourless by animal charcoal, without diminishing its purgative qualities.

Scammony is a drastic purgative, operating usually both rapidly and powerfully. The dose is from 5 grains to 15 grains. It is much used when the bowels are in a torpid state, and, of course, difficult to move. It is usually given in powder, in the form of an electuary. The ancients were acquainted with this gum resin. Dioscorides describes the mode of collecting it, and mentions its medicinal virtues with a good deal of minuteness.*

M. Planche has found that when scammony is triturated with milk, an emulsion is formed, and the whole scammony is held suspended. He considers this as an excellent way of administering this purgative. His formula is the following :—

℞ Resin of scammony, discoloured by animal charcoal gr. viii.
Milk, either hot or cold . . . . . ʒ iii.
Refined sugar . . . . . ʒ ii.
Laurel water, three or four drops
Triturate together.†

SECTION III.—OF GAMBOGE, OR GUMGUTT.

The tree which is supposed to yield this gum resin has not been very well determined. Wight and Arnot, in their *Prodromus of the Botany of India*, state the plant producing it to be the *Xanthochymus ovalifolius*. Dr Graham of Edinburgh affirms that it is undoubtedly the *Garcinia Morella* of Desrousseaux and Gærtner. Arnot now thinks it the *Garcinia Zeylanica*. Dr Graham conceives that the *garcinia morella* is not a *garcinia*, but a *stalagmitis*, or rather represents the type of a new genus, which he proposes to term *Hebradendron*.‡ In the 13th number of the *Madras Journal of Literature and Science*, p. 300, Dr Wight has made some observations on Dr Graham's statement. He says, that the specimen sent to Dr Graham, by Mrs Walker, was from a tree not indigenous in Ceylon, but growing in an old Dutch garden. Hence he concludes, that it is not the *Hebradendron* of Dr Graham which yields the common gamboge of Ceylon, and he still suspects that it comes from the *Xanthochymus ovalifolius*. But the subject requires further investigation, and I have little doubt that Dr Wight will find some means of gaining accurate information.

The tree yielding it is a native of Siam, and of the island of Ceylon, where it is known by the name of *Ghokata*, *Gokkata*, and *Golatha*. It is said also, to be the produce of the *cambogia gutta*, and the *hypericum bacciferum*, and *cayanense*. In Siam it is obtained in drops, by breaking the leaves and young shoots; in Ceylon from the bark, which is wounded with a sharp stone, at the time of the flowering of the tree. It is imported to this country in three states; viz. *pipe gamboge*, *cake*, and *lump*, or *coarse gamboge*. The first is the finest, and sells at from two shillings and tenpence, to five shillings per

* Lb. 4. c. 71. † Jour. de Pharmacie, xviii. 184.
‡ British Annals of Medicine, i. 330.

pound, exclusive of duty. The *cake* gamboge is a little inferior, and the *coarse* very much. But the different qualities have been recently examined by Dr Christison, who found the constituents as follows:—

	Cake.		Lump.		Coarse.	
	1.	2.	1.	2.	1.	2.
Resin .	74·2	71·6	64·3	65·0	61·4	35·0
Arabin .	21·8	24	20·7	19·7	17·2	14·2
Moisture .	4·8	4·8	4	4·2	7·2	10·6
Lignin .	Trace	Trace	4·4	6·2	7·8	22
Starch .	—	—	6·2	5	7·8	19·0
	100·8	100·4	99·6	100·1	101·4	100·8*

Gamboge was first brought to Europe by Admiral Van Neck, in 1603.† It comes chiefly, if not entirely, from the East Indies. Its colour is yellow; it is opaque, brittle, and breaks vitreous. It has no smell, and very little taste. With water it forms a yellow turbid liquid. Alcohol dissolves it almost completely; and when mixed with water becomes turbid, unless the solution contain ammonia. In that case acids throw down an insoluble yellow precipitate. It operates, when taken internally, as a most violent cathartic. Its specific gravity is 1·221.‡

Braconnot analyzed it, and found it composed of 1 part of a gum, which possessed the properties of cherry-tree gum, and 4 parts of a reddish brittle resin, which possessed the characteristic properties of the resins. It dissolved in alcohol and alkalies, and by nitric acid was converted into a yellowish bitter matter. Chlorine deprived it of its dark colour, and a combination took place between it and muriatic acid, in which it neutralized that acid.§

Potash ley dissolves gamboge, assuming a very strong orange colour.

The *resin* of gamboge cannot be separated from the *gum* by means of alcohol; we must have recourse to ether. The resin remaining after the evaporation of the ether is hyacinth red, translucent, and when reduced to powder, the colour becomes yellow. It has neither taste nor smell. It may be fused by heat. It combines with the alkalies; the compounds are deep red; those with the alkaline earths and earths are yellow, and insoluble in water. The same colour have the resinates of the colourless metals. The resinate of tin is a splendid yellow powder, that of iron brown, and that of copper green. The resinate of lead contains, according to Pelletier, half its weight of oxide of lead.

Gamboge is employed in water-colour painting, constituting a very pure and fine yellow. It is a powerful drastic cathartic, and frequently excites vomiting, even in moderate doses. It is usually administered in the state of pills, in doses of from 2 to 6 grains.

* British Annals of Medicine, i. 330, 363.

† See Anatomia Essentiarum Vegetabilium of Angelus Salu, p. 31.

‡ Brisson.

§ Ann. de Chim. lxviii. 33.

The alkaline solution of it has been occasionally employed as a hydragogue in cases of dropsy.

DIVISION IV.—OF SEDATIVE GUM RESINS.

The name by which I have distinguished this class of gum resins will probably be objected to as improper. But those belonging to it are so different from the others, that they require to be placed by themselves, and no name more applicable to them all has suggested itself to me.

SECTION I.—OF OPIUM.

Opium (in Greek οπιον) is the milky juice which exudes when incisions are made into the heads of the *papaver somniferum*, a well known poppy, which was probably originally a native of Asia, from which it gradually made its way into Europe. The milky juice is inspissated into a dark-coloured solid matter by exposure to the atmosphere. It was known to the ancients, being mentioned both by Theophrastus and Dioscorides, and also by Pliny under the name of *opion;* though I have no where met in any ancient author with an accurate account of the way in which it was prepared. Both Dioscorides and Pliny describe it as the inspissated decoction of the heads of the poppy. The ancients were acquainted with its soporiferous effects, and with its poisonous nature when taken in too great quantity.

Dioscorides enumerates various diseases in which its administration was attended with beneficial effects; showing that it was employed in his time in medicine. Paracelsus was the first among modern physicians who brought it into vogue. He administered it freely to alleviate pain, and was indebted to it for not a small part of the high reputation which he acquired as a practitioner.

Ever since the time of Paracelsus, various preparations of opium have been in common use among physicians. Paracelsus exhibited it in pills and in a liquid form, to which he gave the name of *laudanum*,* but the composition of which he kept secret. In the year 1631, the method of making several different kinds of *laudanum opiatum*, was published by Dr John Hartmann, in his *Praxis Chymiatrica* (p. 46). And in the *Pharmacopée Royale Galenique et Chimique* of Charas, published in 1676, there is a long dissertation on laudanum, which the author commences by affirming that the simple extract of opium is a better preparation than any laudanum whatever.

Opium comes to this country from the Levant in rounded masses of a brown colour, and about the size of the fist. Its surface is covered with the seeds of a species of rumex, in which the fresh opium, while still moist, had been rolled up to prevent the pieces from sticking to each other. It is usually hard; though sometimes it retains enough of water to keep it moist. It has a peculiar odour, which is increased by heating it. This odour is to most persons

* Supposed to be a corruption of the word *laudandum*.

disagreeable. Its taste is very bitter. When steeped in water it softens, and the whole may be reduced to the state of a pap. Common spirits is a better solvent of opium than either alcohol or water. It has been often analyzed, though no confidence can be put in the results hitherto obtained. John gives its constituents as follows:—

Rancid fatty matter . . .	2
Hard resin	12
Soft resin	10
Elastic matter	2
Morphin and narcotin . .	12
Balsamic extract . . .	1
Extractive	25
Meconates of lime and magnesia	2·5
Poppy skins	18·5
Water	15
	100

The science of chemistry had made considerable progress before any successful attempt could be made to investigate the constituents of opium. The first step was made by M. Derosne in 1803,* by the discovery of the alkaline principle, now distinguished by the name of *narcotina*. In 1817, M. Sertuerner, an apothecary at Embeck in Hanover, published the result of his experiments on opium, which had occupied him for several years.† He discovered an acid in opium, which he distinguished by the name of *meconic*,‡ and a very active narcotic principle, to which he gave the name of *morphina*.

About the year 1830, M. Couerbe announced the discovery of another new principle in opium, to which he gave the name of *meconin*. The existence of this substance in opium was at first called in question by M. Robiquet; but the accuracy of M. Couerbe's statements was afterwards proved by the subsequent labours of Couerbe and Pelletier. Indeed *meconin* had been discovered by Dublanc in 1826. He published a detailed description of its characters, but neglected to give it a name.§

In 1832, an elaborate analysis of opium was published by M. Pelletier, who had already distinguished himself by his discoveries in vegetable chemistry. He detected and described a new alkaline principle, to which he gave the name of *narceina*.‖

Soon after, M. Robiquet, in repeating the process of Dr Gregory for preparing morphina, detected another principle in opium, to which he gave the name of *codeina*.¶

Finally, M. Theboumery discovered a sixth principle in opium, to which he gave the name of *paramorphin*, but which M. Couerbe who repeated his experiments, and examined the nature of his new substance, changed for *thebaina*.**

Thus the number of peculiar substances which have been found in opium, (not reckoning meconic acid, caoutchouc, bussarin, resin,

* Ann. de Chimie, xlv. 287. † Gilbert's Annalen, lv. 56.

‡ From the Greek word μηκων, *a poppy*.

§ Ann. de Chim. et de Phys. xlix. 5. ‖ Ibid. l. 240.

¶ Ibid. li. 259. ** Ibid. lix. 153.

&c.) are no fewer than six, namely, *narcotina*, *morphina*, *meconin*, *narceina*, *codeina* and *thebaina*, all of which have been described in a previous Chapter of this work.

Opium differs very much in its qualities. M. Mulder* has analyzed five different specimens from Smyrna, and obtained the following results:—

	1.	2.	3.	4.	5.
Narcotina	6·808	8·150	9·360	7·702	6·546
Morphina	10·842	4·106	9·852	2·842	3·800
Codeina	0·678	0·834	0·848	0·858	0·620
Narceina	6·662	7·506	7·684	9·908	13·240
Meconin	0·804	0·846	0·314	1·380	0·608
Meconic acid	5·124	3·968	7·620	7·252	6·644
Fat	2·166	1·350	1·816	4·204	1·508
Caoutchouc	6·012	5·026	3·674	3·754	3·206
Resin	3·582	2·028	4·112	2·208	1·834
Gummy extract	25·200	31·470	21·834	22·606	25·740
Gum	1·042	2·896	0·698	2·998	0·896
Mucus	19·086	17·098	21·064	18·496	18·022
Water	9·846	12·226	11·422	13·044	14·002
	97·852	97·504	100·858	97·252	96·666

Schindler gives the following as the result of a comparative analysis of opium from different places:—

	From Smyrna.	From Constantinople.	From Egypt.
Morphina	10·30	4·50	7·00
Codeina	0·25	0·52	
Meconin	0·08	0·30	
Narcotina	1·30	3·47	2·68
Narceina	0·71	0·42	
Meconic acid	4·70	4·38	
Resin	10·93	8·10	
Lime	0·40	0·02	
Magnesia	0·07	0·40	
Alumina, oxide of iron, silica, and phosphate of lime	0·24	0·22	
Salts and volatile oil	0·36	0·36	
Mucilage, caoutchouc, fat and lignin	26·25	17·18	
Brown acid, soluble in alcohol and water	1·04	0·40	
Brown acid, only soluble in water, gum, and loss	40·13	56·49	
	96·72	96·76†	

* Mulder's Natuur-en Schechundig-Archief, ii. 507.

† Pharm. Centr. Bl. 1834. No. 60, p. 950.

In Turkey, China, and other eastern countries, opium is used in great quantities to induce intoxication. The use of opium as a medicine in this country is so general, and it is employed in such a great variety of diseases, that for an account of the medicinal virtues of this important drug, I must refer to the writers on *Materia Medica*, almost all of whom treat of it at considerable length.

SECTION II.—OF LACTUCARIUM.

This name was applied by Dr Duncan, of Edinburgh, to a gum resin formed from the milky juice which exudes from the *lactuca sativa*, or common garden lettuce. The leaves and stem of this plant, immediately under the cuticle, contain a secreted juice, which is pellucid and colourless when in the vessels of the plant, but becomes milky when exposed to the air, and afterwards acquires a brownish colour, like that of East India opium.

Lactucarium is obtained by cutting the stem of the lettuce at the time of flowering, imbibing the milky juice that flows out by a sponge or by cotton, and squeezing it out into a vessel containing a little water. It is then left in a dry place till it concretes into a solid mass.

It is brown, brittle, and has a bitter taste. It softens when exposed to a moist air, and is soluble in water. The solution has a brownish-yellow colour, reddens litmus paper, and ammonia throws down from it phosphate of lime. The infusion of nutgalls produces also an abundant precipitate, the nature of which has not been examined. It is also precipitated by nitrate of barytes, oxalate of ammonia, nitrate of silver and alcohol. Caventou and Boullay endeavoured in vain to discover in it a vegetable alkaloid.

Lactucarium is occasionally employed in medicine. Dr Coxe, of Philadelphia, recommended it as a substitute for opium. The late Dr Duncan, senior, of Edinburgh, paid a great deal of attention to it, and was in the habit of collecting it for many years. He considered it as particularly well adapted for allaying the cough in phthisis pulmonalis. It is usually administered in pills, of from 1 grain to 6 grains in weight.

SECTION III.—OF UPAS.

This is a name given by the inhabitants of the East Indian Archipelago to a deadly poison, which they employ to poison their weapons, in order to render the slightest wound which they inflict fatal. For the investigation of the nature of this poisonous substance, we are indebted to MM. Pelletier and Caventou.*

There are two kinds of upas, distinguished by the names of *upas tieuté*, and *upas anthiar*. The latter of these is a gum resin, which exudes from the *Anthiaris toxicaria ;* the former is an extract from the *strychnos tieuté*, a tree which grows in Borneo. The great resemblance which these two substances bear to each other must be

* Ann. de Chim. et de Phys. xxvi. 44.

our apology for describing them both here; though the first is not strictly entitled to the name of gum resin.

(1.) *Upas tieuté.* This is by far the most terrible of vegetable poisons. The specimen examined by Pelletier and Caventou had been deposited, by M. Leschenault, in the museum of the Jardin du Roy in Paris, and had been given to these eminent chemists for analysis by the curators of the museum.

It has a reddish-brown colour, or when in thin slices it is reddish-yellow, and translucent. Its taste is intensely bitter, but not acrid. Water dissolves it, leaving a brick-red residuum. The solution is yellow, and when concentrated lets fall an additional quantity of the same residuum. Alcohol dissolves it more completely than water, but it is little soluble in ether, and insoluble in oils.

It contains, besides *igasurate of strychnina*, two extractive matters, one of which becomes *green*, and the other *red*, when treated with the concentrated acids, and in particular with nitric acid. To the first of these substances, Pelletier and Caventou have given the name of *strychochromin*.

It precipitates at the same time with the strychnina, when to the solution of the upas another weak base is added, and dissolves along with it in acids. It is to its presence that strychnina owes the property of assuming a green colour when treated with concentrated nitric acid. It has a strong affinity for charcoal, and separates both from upas and strychnina when they are digested with recently calcined charcoal. Concentrated nitric acid gives it a deep green colour, which disappears when the acid is diluted with water, or when an alkali or a disoxygenizing body (as protochloride of tin) is added. Sulphuric acid gives it a weaker green colour, and acetic acid a still weaker. Muriatic acid does not change its colour. The *apotheme* produced from this upas contains a certain quantity of strychochromin, and this is the reason why it is coloured green by nitric acid. The alkalies dissolve this apotheme, assuming a deep colour. Hot alcohol also dissolves it, but during the cooling it is again deposited in scales which are insoluble in ether.

The other extractive matter remains in solution in the liquor from which the strychnina had been precipitated by magnesia, and the strychochromin by charcoal. Pelletier and Caventou did not succeed in obtaining it in a state of purity. Its solution is yellow, and when evaporated gives an extractive substance, soluble in water and in alcohol. It is not precipitated from its solution by acetate of lead, nor by digestion with animal charcoal. Nitric acid gives it a red colour, but when a disoxidizing body (sulphurous acid or protochloride of tin, for example,) is added, the red colour disappears. It is this substance which gives to strychnina, extracted from *nux vomica*, or from *St Ignatius's beans*, the property of becoming red when treated with nitric acid.

Upas tieuté acts as a poison precisely as strychnina does. The inhabitants of Borneo dip the points of their arrows (usually made of bone), into concentrated upas tieuté, in order to make the wounds

inflicted by them fatal. The consequence is the inducement of tetanus, which frequently destroys life within a quarter of an hour after the wound has been given.

(2.) *Upas anthiar.* This is a gum resin which exudes from the *anthiaris toxicaria*, in the form of a milky juice, which concretes into a reddish-brown matter of the consistence of wax. Its taste is very bitter, and it leaves an acrid impression in the mouth. Water dissolves a portion of it into a brownish emulsion. Alcohol is a better solvent than water; but ether dissolves very little of it. When heated it melts, swells, and gives out ammonia.

According to the experiments of Pelletier and Caventou, when it is boiled with water a resin separates, which melts and swims on the surface of the liquid. This *resin* is insoluble in water. When heated in that liquid to 180° or 190°, it acquires a much greater degree of elasticity than caoutchouc. This it preserves for some time; but at last it becomes so brittle that it may be reduced to powder. It is insoluble in cold alcohol, but boiling alcohol softens it and dissolves a little of it, which precipitates in white flocks when the liquid cools. Ether and the volatile oils dissolve it with facility.

The aqueous solution, from which this resin had been separated, leaves, when filtered, a substance analogous to salop, seemingly a vegetable *mucilage*. When the filtered liquor is evaporated, pellicles of the same mucilage form on its surface, which may be precipitated by alcohol, as soon as the liquid has acquired a certain degree of concentration.

The alcohol retains in solution a particular substance, which seems to constitute the active part of the *upas anthiar*. It is deposited during the evaporation of the alcohol in crystalline grains of a brownish-yellow colour. It has a very bitter taste, and dissolves readily in water and alcohol; but ether does not dissolve it. Its aqueous solution possesses weak alkaline properties. Pelletier and Caventou conjecture that it may be an alkaloid, though it is not precipitated from its solutions by ammonia or hydrate of lime. Infusion of nutgalls precipitates it, and the precipitate is soluble in alcohol—a property which belongs to most of the combinations of the alkaloids with tannin. This substance has been distinguished by the name of *anthiarin*.

The natives of the Indian islands employ the upas anthiar, as well as the upas tieuté, to poison their arrows; but the former is not nearly so poisonous as the latter. They are obliged, in consequence, to apply it to their arrows in much greater quantity.

CLASS IV.

OF NEUTRAL VEGETABLE PRINCIPLES.

By neutral vegetable principles are meant those vegetable bodies, which neither possess the properties of acids nor bases, and which, so far as is known at present, do not combine in definite proportions with other substances.

These neutral bodies are pretty numerous, and some of them of so anomalous a nature, that it is not easy to arrange them under general heads. I shall, however, for the sake of convenience, classify them under the thirteen following general Divisions:—

I. Amides, or amidets.
II. Benzoyl and its compounds.
III. Spiroil and its compounds.
IV. Sugars.
V. Amylaceous substances.
VI. Gums.
VII. Glutinous substances.
VIII. Caoutchouc.
IX. Extractive.
X. Bitter principles.
XI. Products of destructive distillation of vegetable substances.
XII. Neutral compounds, sometimes containing azote.
XIII. Some compounds of azote.

CHAPTER I.

OF AMIDES, OR AMIDETS.

The term *amide* has been already explained in the Introduction to the present Volume. It signifies an anhydrous ammoniacal salt deprived (if an expression, apparently contradictory, may be allowed) of an atom of water. The number of *amides* is still but inconsiderable; but it will doubtless greatly increase, as vegetable chemistry advances.

SECTION I.—OF OXAMIDE.

This substance, the first of the series of amides, was discovered by Dumas, in the year 1830.*

When oxalate of ammonia is heated in a glass retort, it loses, in

* Ann. de Chim. et de Phys. xliv. 129.

the first place, its water of crystallization, and the crystals become opaque. The salt then melts and boils, but only in those parts of the mass which receive immediately the impression of the heat. Those portions which melt undergo decomposition and disappear rapidly; but the mass in general retains its appearance, and a careful examination is necessary to be able to perceive the thin layer of the salt which is in a state of fusion. When the distillation is at an end some trace of charcoal merely remains in the retort; all the rest has been volatilized.

In the receiver we find water strongly impregnated with carbonate of ammonia. This water holds in suspension a flocky matter of a dirty-white colour. The neck of the retort exhibits usually crystals of carbonate of ammonia, and likewise a thick layer of the same white matter. The white flocks and deposit on the beak of the retort constitute the substance called *oxamide*. To obtain it in a state of purity the whole is washed out upon a filter and thoroughly edulcorated with cold water. Being nearly insoluble, it remains on the filter.

Gas is disengaged during the whole process of distillation; but it changes its nature as the distillation proceeds. At first we obtain ammonia, soon after carbonic acid gas, and consequently carbonate of ammonia. This salt is partly dissolved in the water, partly in crystals in the receiver, and partly in the beak of the retort. Mixed with the carbonic acid is carbonic oxide, which appears at first to be in much greater quantity than the acid gas; because this latter is absorbed by the ammonia. After the ammonia is saturated the volumes of the two gases disengaged appear to be equal. Towards the end of the distillation, cyanogen gas is disengaged, mingled with the other two gases in very variable proportions. Thus it appears that when oxalate of ammonia is distilled, we obtain ammonia, water, carbonate of ammonia, carbonic acid gas, carbonic oxide, cyanogen, and oxamide. This last in very small quantity, not exceeding 4 or 5 per cent. of the oxalate of ammonia employed.*

The oxamide is obtained in confusedly crystallized plates, or in a granular powder. Here and there brown spots appear on it, produced by a substance analogous to azulmic acid. When pounded and well washed it is a dirty-white powder, resembling uric acid, without taste or smell, or any action on vegetable colours.

It is volatile. When cautiously heated in an open tube it is sublimed and crystallizes confusedly. But if we put it into a retort and attempt to distil it, imperfect fusion takes place in those parts that are most heated. It sublimes partially, and is partially decomposed, cyanogen being formed. A very bulky and light brown charcoal remains.

Oxamide is not sensibly soluble in cold water. In boiling water it dissolves, but is again deposited in imperfect crystals as the liquid cools.

* Liebig has shown that when caustic ammonia is added to oxalic ether, alcohol is evolved, and a copious deposit of oxamide is produced. This is by far the most economical method of preparing oxamide. See Ann. der Pharmacie, ix. 129.

When oxamide is heated in sulphuric acid it dissolves, and gas is given out in abundance. This gas consists of equal volumes of carbonic acid and carbonic oxide. At the same time a quantity of ammonia is formed which combines with the acid. When boiled in a concentrated solution of potash it gives out ammonia in abundance. At the same time oxalic acid is formed, which combines with the potash.

From a very careful analysis of oxamide by M. Dumas, its constituents appear to be

Carbon . . .	26·98 or 2 atoms	= 1·5
Hydrogen . . .	4·59 or 2 atoms	= 0·25
Azote . . .	31·67 or 1 atom	= 1·75
Oxygen . . .	36·79 or 2 atoms	= 2·00
	100·00	5·5

We see from this analysis that it is $C^2\ O^2 + H^2\ Az$. If we add H O (an atom of water) the oxamide becomes $C^2\ O^3 + H^3\ Az$, or oxalate of ammonia.*

SECTION II.—OF OXAMETHANE, OR ETHEROXAMIDE.

M. Dumas† passed a current of dry ammoniacal gas over a given quantity of pure oxalic ether. The matter being solidified, it was heated, and the current of gas continued for some time longer. The substance thus obtained he called *oxamethane*. 100 parts of ether, treated in this manner, furnished 76 or 77 of oxamethane.

It melts at a temperature below 212°, but is not volatilized under 428°. When sublimed it crystallizes in beautiful radiated plates. It dissolves in alcohol without alteration. When put into water, that liquid becomes very acid, and probably alcohol and binoxalate of ammonia are formed. It was analyzed by Dumas and Boullay indirectly, and afterwards directly by Dumas, with the following result:—

Carbon	40·725
Hydrogen	5·990
Azote	12·345
Oxygen	40·940
	100·000

It was analyzed by Mitscherlich with the same result.‡ The mean of both analyses is

Carbon	41·50 or 8 atoms	= 6	or per cent.	41·02
Hydrogen	6·06 or 7 atoms	= 0·875	— —	5·99
Azote	11·81 or 1 atom	= 1·75	— —	11·97
Oxygen	40·63 or 6 atoms	= 6·00	— —	41·02
	100·00	14·625		100

* Ann. de Chim. et de Phys. xliv. 129.—See also Plisson and Henry, Jour. de Pharmacie, xvii. 177.

† Ibid. liv. 241.

‡ Poggendorf's Annalen, xxxiii. 333.

These atoms may be resolved into

2 atoms oxalic acid .	$C^4\ O^6$
1 atom ether . .	$C^4\ O\ H^5$
1 atom ammonia . .	$H^3\ A^2$
	$C^8\ O^7\ H^8\ A^2$
Minus 1 atom water	$O\ H$
	$C^8\ O^6\ H^7\ A^2$

So that it wants 1 atom of water in order to be a compound of 1 integrant particle of oxalic ether, and 1 integrant particle of oxalate of ammonia. It is, therefore, a compound of oxamide and oxalic ether. Hence the reason why by Mitscherlich it is denominated *etheroxamide*.

SECTION III.—OF SUCCINAMIDE.

When ammoniacal gas is made to act upon anhydrous succinic acid water is formed, and the temperature is considerably elevated. The new substance formed by this action being much more fusible than succinic acid, melts, and is volatilized. And this process continues till the whole succinic acid is converted into *succinamide*. The reaction is assisted by the application of heat.

The substance which M. Darcet has distinguished by the name of *succinamide* is a white solid, possessed of none of the properties of succinic acid, and crystallizing readily in rhomboids. It is but little soluble in ether, but pretty soluble in alcohol, and very soluble in water. From each of these solutions it is easily obtained in regular crystals.

M. Darcet subjected it to an ultimate analysis by means of oxide of copper, and obtained

Carbon	48·07 or 8 atoms	= 6	or per cent.	48·48
Hydrogen	5·52 or 5 atoms	= 0·625	— —	5·05
Azote	15·28 or 1 atom	= 1·75	— —	14·15
Oxygen	31·13 or 4 atoms	= 4	— —	32·32
	100	12·375		100·00

The action between the succinic acid and ammonia will be more easily understood, if we take the half of the preceding number.

4 atoms carbon . .	= 3
$2\frac{1}{2}$ atoms hydrogen . .	= 0·3125
$\frac{1}{2}$ atom azote . . .	= 0·875
2 atoms oxygen . .	= 2
	6·1875

Succinic acid is $C^4\ H^2\ O^3$ and 2 atoms $C^8\ H^4\ O^6$

Ammonia $H^3\ Az$ $H^3\ Az$

$C^4\ H^5\ Az\ O^3$ $C^8\ H^7\ Az\ O^6$

We see that, with every 2 atoms of succinic acid 1 atom of azote has combined, while 2 of the atoms of the hydrogen of the ammonia have abstracted 2 atoms of the oxygen of the acid, and converted them into water. The other atom of hydrogen enters into the composition of the succinamide.

Thus, 2 atoms succinic acid	.	$C^8\ H^4\ O^6$
1 atom ammonia	.	$H^3\ Az$
		$C^8\ H^4\ O^6 + H^3\ Az$
2 atoms succinamide		$C^8\ H^4\ O^4 + H\ Az$
Abstracted 2 atoms water		$O^2 + H^2$

When succinamide is dissolved in water and crystallized, the crystals consist of an atom of succinamide, combined with one atom of water.

When succinamide is treated with potash, ammonia is disengaged, and the temperature rises.

When dry succinate of lime, or succinic acid and lime mixed in the atomic proportion, are distilled, we obtain a brown liquid, having an empyreumatic smell. When this liquid is repeatedly distilled slowly, at a temperature not exceeding 248°, we obtain a colourless liquid, very nearly destitute of the empyreumatic smell. Only a very small quantity of this matter, which Darcet has called *succinone* has been obtained; so little, indeed, that its properties have not been accurately determined. M. Darcet analyzed it by means of oxide of copper, and obtained

Carbon	78·81 or 17 atoms	= 12·75	or per cent.	79·07
Hydrogen	8·72 or 11 atoms	= 1·375	— —	8·53
Oxygen	12·47 or 2 atoms	= 2·00	— —	12·40
	100·00	16·125		100·00

This substance requires farther investigation. It is doubtless analogous to benzone, which is procured by a similar process.

SECTION IV.—OF BENZAMIDE.

This substance was discovered by MM. Wöhler and Liebig,* and named by them from its great resemblance to oxamide, both in its characters and mode of formation.

When dry ammoniacal gas is made to pass through pure chloride of benzoyle it is absorbed, the temperature is greatly elevated, and the liquid changes into a white solid body. This substance is a mixture of sal ammoniac and *benzamide*. It is difficult to saturate the chloride of benzoyl completely with ammonia; because the solid matter prevents the gas from coming in contact with the liquid portion. It is necessary to take the mixture repeatedly out of the vessel, to subject it to pressure in order to separate the solid from

* Ann. de Chim. et de Phys. li. 293.

the liquid portion, and to replace the liquid part and subject it anew to the ammonia current.

To reduce the benzamide formed to a state of purity, the white matter obtained is washed in cold water, and then dissolved in hot water and allowed to crystallize on cooling. If the ammoniacal gas was not quite dry, benzoate of ammonia is formed during the process, at the expense of the benzamide.

When the boiling-hot solution of benzamide is cooled rapidly, large brilliant crystals are deposited similar to those of chlorate of potash. But if the solution be cooled slowly, the whole liquid assumes the form of a white mass composed of silky needles similar to the crystals of caffein. After one or two days, or sometimes earlier, large cavities are formed in the mass in which some well-shaped crystals appear. By degrees the whole silky crystals undergo this transformation.

The crystals of benzamide are right rhombic prisms, having their acute edges replaced by tangent planes. Two of the faces being much larger than the others, the crystals usually appear under the form of four-sided tables with bevelled edges. These crystals have a pearly lustre, they are transparent, and swim on water as if they were oily.

At 239° benzamide melts into a limpid liquid, which on cooling congeals into a foliated crystalline mass. When strongly heated it boils, and may be distilled over unaltered. Its vapour has a slight smell of almond oil. It easily catches fire, and burns with a fuliginous flame.

It is so little soluble in cold water that it scarcely communicates any flavour to that liquid. But it dissolves very readily in alcohol. Ether dissolves it also at a boiling temperature, and we can obtain it from that solution in regular crystals.

If benzamide, at the ordinary temperature of the atmosphere, be sprinkled over with caustic potash, not the smallest trace of ammonia can be detected. When the solution is mixed with a solution of iron at the ordinary temperature, no precipitate falls. Nor indeed does any metallic salt whatever occasion any precipitate in it. But if we boil the solution of benzamide with caustic potash, abundance of ammonia is disengaged and benzoate of potash formed. When a solution containing peroxide of iron is raised to the boiling temperature, a subbenzoate of iron is precipitated.

If we dissolve benzamide in a strong acid, and raise the solution to the boiling temperature, the benzamide disappears, and benzoic acid separates from the solution, while at the same time a salt of ammonia is formed. When we employ concentrated sulphuric acid the benzoic acid formed sublimes. When benzamide is boiled with water, that decomposition into benzoic acid and ammonia does not take place.

Benzamide was analyzed by MM. Wöhler and Liebig, by means of oxide of copper. They obtained

Carbon	68·93 or	14 atoms =	10·5	or per cent.	69·43
Hydrogen	5·78 or	7 atoms =	0·875	— —	5·78
Azote	11·48 or	1 atom =	1·75	— —	11·57
Oxygen	13·81 or	2 atoms =	2·00	— —	13·22
	100		15·125		100·00

Now chloride of benzoyl is $C^{14}\ H^{5}\ O^{2} + Chl$

Add 2 atoms of ammonia $Az^{2}\ H^{6}$

We have $C^{14}\ H^{5}\ O^{2} + Chl + Az^{2}\ H^{6}$

Subtracting 1 atom sal ammoniac $H \quad Chl + Az\ H^{3}$

We get $C^{14}\ H^{5}\ O^{2} \quad + Az\ H^{2}$

which is the composition of benzamide.

Thus the way in which chloride of benzoyle and ammonia are capable of forming benzamide and sal ammoniac is evident. The addition of an atom of water changes the benzamide into benzoate of ammonia.

When benzamide is heated with an excess of caustic barytes, it enters into a kind of fusion; the barytes is changed into a hydrate, ammonia is disengaged, while at the same time a colourless oily-looking liquid distils over. It has an aromatic and agreeable smell, and a peculiar sweet taste. It is neither altered by the concentrated acids nor alkalies. Potassium may be melted in it without undergoing any alteration, demonstrating the absence of oxygen. The same substance is developed in considerable quantity, and without being accompanied by ammonia, when benzamide is fused with potassium, during which the potassium is converted into a cyanodide.

When benzamide is made to pass through a red hot tube, the greatest part of it continues unaltered; but mixed with a little of the oily substance just mentioned. No deposition of charcoal takes place.

SECTION V.—OF BENZIMIDE, OR BIBENZAMIDE.

This name (too near the preceding) has been given by M. Laurent to a substance extracted by him from a resinous body, obtained by M. Ed. Laugier, while distilling the oil of bitter almonds,* and which he found afterwards to be a constant product.†

The resinous substance was found to contain, at least, three ingredients, an oil, benzoin and benzimide. When treated with hot alcohol, the oil and benzoin remain in solution; but the benzimide is deposited as the liquid cools. It may be purified by repeated crystallizations.

It is a white solid, in very light flocks, with a pearly lustre, and destitute of smell. It is insoluble in water, but very soluble in alcohol and ether, and still more soluble in pyroxylic spirit. It

* Ann. de Chim. et de Phys. lix. 397. † Ibid. lx. 218.

melts and is volatilized without decomposition. It becomes again solid when cooled down to 332°½. It burns with a red flame, giving out smoke, leaving a brownish-black residue. Nitric acid dissolves it when assisted by heat without disengagement of red vapours, and it is not precipitated by ammonia. Boiling muriatic acid dissolves it. Nordhausen sulphuric acid dissolves it, assuming a deep indigo colour, provided the benzimide be perfectly dry. If moisture be present, the colour is at first emerald green, then yellow. Potash ley does not attack it, but if a little alcohol be added, ammonia is disengaged and benzoate of potash formed.

Benzimide was analyzed by Laurent, who obtained

Carbon	76·53 or 28 atoms	= 21	or per cent.		74·66
Hydrogen	4·95 or 11 atoms	= 1·375	—	—	4·88
Azote	7·00 or 1 atom	= 1·750	—	—	6·23
Oxygen	11·52 or 4 atoms	= 4·000	—	—	14·23
	100·00	28·125			100

Now 2 atoms benzoic acid are	C^{28}	H^{10}	O^{6}	
1 atom ammonia				H^{3} Az
Bibenzoate of ammonia is	C^{28}	H^{10}	O^{6} +	H^{3} Az
Subtract 2 atoms water			O^{2} +	H^{2}
There will remain	C^{28}	H^{11}	O^{4}	Az

which is an atom of benzimide. We see from this, that benzimide is bibenzoate of ammonia deprived of two atoms of water. It is therefore analogous to *benzamide*, and might perhaps be distinguished by the name *bibenzamide*. The term *benzimide* is too near *benzamide* to be adopted by chemists in general.

SECTION VI.—OF ASPARAMIDE.

This substance, under the name of asparagin, was discovered in the juice of the *Asparagus officinalis*, by Vauquelin and Robiquet in the year 1806.* In 1827, M. Bacon discovered a principle in the root of the *althæa officinalis*, or *marsh mallow*, to which he gave the name of *althein*.† Henry and Plisson repeated the experiments of Bacon, and showed that his althein was the same with the asparagin of Vauquelin and Robiquet. M. Robiquet in 1809 had discovered a substance in the root of the *glycyrrhiza glabra*,‡ or common *liquorice*, to which Caventou afterwards gave the name of *agedoite*. This substance was further examined by M. Plisson, and shown by him to be identical with asparagin.§ In the year 1830, M. Wittstock repeated the experiments of the French chemists,‖ and rendered it probable that the asparagin obtained from the root of the *althæa officinalis* was formed during the process of extraction, and did not pre-exist ready formed in that root.

* Ann. de Chim. lvii. 88. † Ann. de Chim. et de Phys. xxxiv. 201.
‡ Ann. de Chim. lxxii. 143. § Jour. de Pharmacie, xiv. 177.
‖ Poggendorf's Annalen der Physic, xx. 346.

The best mode of obtaining asparagin from the root of marsh mallow is, according to Wittstock, the following:—The aqueous extract of the root is digested in boiling alcohol, of the specific gravity 0·835, till every thing soluble is taken up. When this solution is set aside for 24 hours, it deposits a pasty matter. Decant off the clear liquor and leave it in a cool place. In 24 hours a crop of small crystals is deposited. These consist of asparagin, and constitute about $\frac{1}{3}$d of a per cent. of the marsh mallow root employed. If we distil off the alcohol from the liquid portion, and mix the residue with that portion of the aqueous extract which was at first left undissolved by the alcohol, and dissolve the whole in water, we may extract from this solution an additional quantity of asparagin. The method of proceeding is as follows:—

Precipitate the liquid by acetate of lead, and throw down the excess of lead by a current of sulphuretted hydrogen gas. Filter the liquid and evaporate to the consistence of a syrup. In 24 hours this syrup assumes the form of a mass of crystals. Dissolve in boiling alcohol, and let the crystals of asparagin, which are deposited from that solution, be dissolved in hot water, and leave this solution to spontaneous evaporation in a temperature between 77° and 95°. The asparagin will crystallize in six-sided prisms, quite white if the aqueous solution has been digested with some ivory black.

Asparagin crystallizes in rectangular octahedrons and six-sided prisms. It has no smell and but little taste. Its specific gravity at 55° is 1·519. When heated it gives out ammoniacal water, showing that it contains azote as a constituent. At 57° it dissolves in 58 times its weight of water, but it is much more soluble in hot water. Alcohol of 0·837 is a much better solvent of it than water; but it is insoluble in absolute alcohol and likewise in ether.

According to Henry and Plisson it may be dissolved in weak potash ley and thrown down from that solution by an acid. When digested with strong potash ley, ammonia is given out, and the asparagin converted into *aspartic acid*. When acids are mixed with it, they combine with ammonia, and aspartic acid is disengaged. This rather confirms the opinion of Wittstock, that asparagin is nothing else than a combination of aspartic acid and water. But if it were so, it is difficult to understand why acetate of lead forms no precipitate, when dropt into a solution of asparagin; though it forms a precipitate when added to an aspartate. Asparagin is not precipitated by the other metalline salts, nor by the infusion of nut-galls.

Anhydrous aspartic acid has been shown to be a compound of $C^8\ H^5\ Az\ O^6$. Of course aspartate of ammonia is composed of $C^8\ H^5\ Az\ O^6 + Az\ H^3$; and asparagin, or asparamide, is $C^8\ H^5\ Az\ O^5 + Az\ H^2$.

SECTION VII.—OF URETHAN, OR ETHER CARBAMIDE.

When chlorocarbonic ether is placed in contact with concentrated caustic ammonia, dissolved in water, a violent action takes place,

the mixture boils, and a kind of explosion sometimes follows. If the ammonia is in excess all the ether disappears; sal ammoniac is formed, and a new substance, which Dumas, the discoverer, has distinguished by the name of *urethan*.*

To procure it we must evaporate, *in vacuo*, the product of the reaction to perfect dryness. The dry matter is then put into a retort, and distilled by the heat of an oil-bath. A colourless liquid passes over, which, on cooling, concretes into plates, having a pearly lustre. If the solution of this substance renders nitrate of silver muddy, we must distil it again, taking care not to raise the heat too high.

Urethan thus obtained is a white solid, fusible below 212°, and capable of being distilled over unaltered at about 226° when dry. But if it be moist, it cannot be distilled over without partial decomposition, much ammoniacal gas being disengaged. It is very soluble in water, both cold and hot. It does not precipitate salts of silver. Nor does its solution react either as an acid or an alkali. It dissolves very well in alcohol, even when anhydrous.

It has so great a tendency to crystallize, that when a few drops of its solution are left to spontaneous evaporation, it always shoots into thin and very transparent crystals. These crystals are anhydrous.

Urethan was analyzed by Dumas, by means of oxide of copper. He obtained

Carbon	40·5 or 3	atoms =	2·25	or per cent.	40·45
Hydrogen	7·9 or $3\frac{1}{2}$	atoms =	0·4375	— —	7·86
Azote	15·6 or $\frac{1}{2}$	atom =	0·875	— —	15·73
Oxygen	36·0 or 2	atoms =	2·000	— —	35·96
	100·0		5·5625		100

Or, doubling the numbers, . . $C^6 H^7 Az O^4$

These atoms may be resolved into

2 atoms carbonic acid	$C^2 \quad O^4$
1 atom ether . .	$C^4 H^5 \quad O$
1 atom ammonia .	$H^3 Az$
	$C^6 H^8 Az O^5$
Minus an atom of water . .	$H \quad O$
	$C^6 H^7 Az O^4$

It may, therefore, be considered as a compound of an integrant particle of carbonic ether, and an integrant particle of carbamide. It is analogous in its composition to *oxamethan*.

Urethan may be represented also by

1 atom carbonic ether	$C O^2 + C^4 H^5 O$ or $C^5 H^5 \quad O^3$
1 atom uric acid	$C H^2 Az O$
	$C^6 H^7 Az O^4$

* Ann. de Chim. et de Phys. liv. 232.

It was in consequence of this isomerism that Dumas gave this new substance the name of *urethan*.

Dumas found the specific gravity of the vapour of urethan to be 3·14. Now, the specific gravity of

6 volumes carbon vapour .	= 2·5
7 volumes hydrogen gas .	= 0·4861
1 volume azotic gas . .	= 0·9722
2 volumes oxygen gas .	= 2·2222
	2)6·1805
	3·09

It is, therefore, composed of 16 volumes condensed into 2 volumes.

SECTION VIII.—OF SULPHAMIDE.

This curious compound was discovered by M. Henry Rose, and described by him in the year 1836.* It is well known that all the salts composed of ammonia, and the oxygen acids, contain water, as an essential constituent, since they cannot be deprived of it without decomposition. Thus sulphate of ammonia, dried on the sand-bath, is $SO^3 + H^3 Az + HO$. Now, since the HO is essential to the salt, the view of the composition given by Berzelius is at least plausible; namely, that it is a compound of an atom of sulphuric acid, with an atom of oxide of ammonium, or $SO^3 + (Az H^4 + O)$.

If we combine dry ammoniacal gas with anhydrous sulphuric acid, we obtain a compound possessing very different properties from those of common sulphate of ammonia. The best mode of proceeding is to introduce the vapour of the anhydrous acid into a large glass receiver, surrounded by a freezing mixture, and continue the process till a very thin coating of the acid is deposited equably upon the inside of the vessel. The dry ammoniacal gas is now passed into the vessel as long as the acid continues to imbibe it. If the coating of sulphuric acid be too thick, the ammonia forms a crust which covers it, and prevents the rest of the acid from being saturated.

The compound thus formed, when neutral, is a white light powder, not altered by exposure to the atmosphere, and dissolves readily in cold water, but is insoluble in alcohol. When we mix it with solution of potash or of lime, the evolution of ammonia becomes immediately evident. But if we bruise it with dry carbonate of barytes or lime, no smell of ammonia is perceptible, till we moisten the mixture with water. When mixed with concentrated sulphuric acid, it gives out no smell of sulphurous acid. When heated with an excess of concentrated sulphuric acid, it dissolves with difficulty, and separates again when the liquid cools.

When heated it melts into a clear liquid, which concretes, on cooling, into a bisulphate of ammonia, if the heat has been continued

* Ann. de Chim. et de Phys. lxii. 389.

too long. The retort contains sulphurous acid in the gaseous state, and in its neck there is sublimed a mixture of sulphate and sulphite of ammonia. In the receiver we find gaseous ammonia and sulphite of ammonia, but no trace of sulphuric acid. This compound was analyzed by M. Rose, who showed that it consisted of

1 atom sulphuric acid . .	5
1 atom ammonia . . .	2·125
	7·125

But these constituents, consisting of $SO^3 + H^3 Az$, were certainly not in their usual state. For the most concentrated solution of the compound was not precipitated by chloride of calcium or chloride of strontium, though these chlorides occasioned a copious precipitate, when mixed with a solution of common sulphate of ammonia. Chloride of barium throws down a precipitate of sulphate of barytes; but the whole sulphuric acid could not be thrown down by this reagent, even after a couple of months' digestion; and never till sufficient heat had been applied to volatilize the ammoniacal salt formed, which requires a heat of ignition.

These facts show clearly, that though the constituents of sulphuric acid and ammonia are present in this compound, they are not in their ordinary state, but combined in some other way. The conjecture of M. Rose, that they constitute an amide, together with an atom of water, is as probable as any which, in the present state of our knowledge, we can form. We may represent the compound thus:—$SO^2 + H^2 Az + HO$, or an atom of sulphurous acid, an atom of amide, and an atom of water, and distinguish it by the name of *sulphamide*.

CHAPTER II.

OF BENZOYL AND ITS COMPOUNDS.

The researches of Wöhler and Liebig, upon the volatile oil of bitter almonds, published in 1832,* have thrown a new and unexpected light on the nature and compounds of the bases of compound vegetable acids. It will be, proper, on that account, to lay a somewhat detailed account of them before the reader.

The volatile oil, or *essence* of *bitter almonds* (as it is called), was observed by Stange to have the property of absorbing oxygen from the atmosphere, and of being converted into benzoic acid. From the researches of MM. Robiquet and Boutron-Charlard, it would appear, that this volatile oil does not exist ready formed in bitter almonds, but only its constituents, and that it is formed by the ac-

* Ann. de Chim. et de Phys. li. 273.

tion of water on these constituents.* It has been long known that the volatile oil of bitter almonds contains a great deal of prussic acid. MM. Wöhler and Liebig obtained the oil which they employed in their researches from M. Pelouze. It had a yellow colour, and the peculiar smell by which it is characterized. They freed it from prussic acid, and the other impurities which it contained, in the following manner:—

It was carefully mixed with hydrate of potash, and a solution of protochloride of iron, and after being well agitated, the mixture was subjected to distillation. All the oil passed over with the water, quite freed from prussic acid. It was separated from the water by means of a sucker, and rectified over quick lime recently slacked and ignited. The oil thus purified is colourless and limpid, and refracts the light strongly. Its smell differs from that of common volatile oil of bitter almonds. Its taste is acrid and aromatic. Its specific gravity is 1·043. Its boiling point is above 266°. Laurent, indeed, found it 356°.† It takes fire easily, and burns with a clear flame, emitting much smoke.

It is not decomposed when passed through a red hot tube. In the air, or in oxygen gas, whether dry or moist, it is converted into crystallized benzoic acid. The light of the sun hastens very much this transformation. It commences in a few minutes. When water and potash are present, we obtain a benzoate of that alkali. If these experiments are made in a glass tube, inverted over mercury, we perceive, by the ascension of the mercury, that the oxygen gas is absorbed. Nothing else is produced but benzoic acid during this transformation of the oil.

It is not altered by the anhydrous fixed alkalies; but when heated in contact of air with hydrate of potash, benzoate of potash is formed, and hydrogen gas disengaged.

If we put the oil in contact with an alcoholic solution of hydrate of potash, or into absolute alcohol, saturated with ammoniacal gas, it dissolves readily, and there is formed (if air be excluded) a benzoate, which precipitates in large brilliant crystals, as soon as potash is added. When water is added, the salt dissolves, and an oil separates, which possesses the properties of oil of bitter almonds.

This oil dissolves, without alteration, in concentrated nitric and sulphuric acids. When the sulphuric acid solution is heated, it becomes reddish-purple, then blackens, and sulphurous acid is disengaged.

This oil was analyzed by Liebig and by Laurent, by means of oxide of copper, and its constituents were found to be

	Liebig.	Laurent.
Carbon . .	78·44	78·28
Hydrogen . .	5·74	5·42
Oxygen . .	15·82	16·30
	100·00	100‡

* Ann. de Chim. et de Phys. xliv. 353. † Ibid. lx. 219. ‡ Ibid.

These numbers correspond with

14 atoms carbon	= 10·5	or per cent.		79·26
6 atoms hydrogen	= 0·75	—	—	5·66
2 atoms oxygen	= 2	—	—	15·08
	13·25			100·00

It is easy, from our knowledge of the constituents of volatile oil of bitter almonds, and of benzoic acid, to explain what happens during the conversion of the oil into the acid.

The oil is . . . $C^{14} H^6 O^2$
Benzoic acid . . . $C^{14} H^5 O^3$

So that the oil contains 1 atom more of hydrogen, and 1 atom less of oxygen, than the acid. 2 atoms of oxygen are absorbed, the one unites with 1 atom of hydrogen, and forms water, while the other combines with ($C^{14} H^5 O^2$), and converts it into benzoic acid. $C^{14} H^5 O^2$ must be the base of benzoic acid, and the oil must be this base combined with an atom of hydrogen, or it must be a *hydret of benzoyl*; for by this name Wöhler and Liebig have distinguished the base of benzoic acid.

SECTION I.—OF BENZOYL.

M. Laurent obtained benzoyl in an insulated state, by passing a current of chlorine gas through *benzoin*,* taking care to keep it in fusion while this gas was passing: muriatic acid was formed, and benzoyl disengaged. He purified it by dissolving it in alcohol, and crystallizing it.†

Thus obtained, it is slightly yellow, destitute of taste and smell, insoluble in water, very soluble in alcohol and ether, from which it crystallizes in regular six-sided prisms, terminated by three pentagonal faces, indicating a rhomboid for the primitive form. Its lustre is vitreous. When ground between the teeth it gives a disagreeable sensation, like that of sulphur, under the same circumstances. It is fusible, and may be volatilized without decomposition. It becomes solid when cooled down to about 196°. On platinum foil it burns with a red flame, giving out smoke. Sulphuric acid dissolves, and water precipitates it from its solution. When heated with potassium it melts, and is a little altered. On increasing the temperature, there is a disengagement of light, accompanied by a violet vapour, and the deposition of charcoal. Potash ley does not alter it, even in a boiling heat, but an alcoholic solution of potash acquires a blue colour, and the benzoyl disappears, if we continue the boiling.

It was analyzed by M. Laurent who obtained

Carbon	79·61 or 14 atoms	= 10·5	or per cent.		80
Hydrogen	4·91 or 5 atoms	= 0·625	—	—	4·76
Oxygen	15·48 or 2 atoms	= 2·000	—	—	15·24
	100·00	13·125			100

Precisely the composition assigned to it by Wöhler and Liebig.

* See it described in a subsequent part of this Chapter.
† Ann. de Chim. et de Phys. lix. 402.

It will facilitate the account of the following compounds, if we state their composition here.

Benzoyl	$C^{14} H^5 O^2$
Hydret of benzoyl (or oil of bitter almonds)	$C^{14} H^5 O^2 + H$
Benzoin	$C^{14} H^5 O^2 + H$
Benzoic acid	$C^{14} H^5 O^2 + O$
Chloride of benzoyl . . .	$C^{14} H^5 O^2 + Chl$
Bromide of benzoyl . . .	$C^{14} H^5 O^2 + Br$
Iodine of benzoyl . . .	$C^{14} H^5 O^2 + Iod$
Sulphuret of benzoyl . . .	$C^{14} H^5 O^2 + S$
Cyanide of benzoyl . . .	$C^{14} H^5 O^2 + C^2 Az$
Benzone .	$C^{13} H^5 O$
Benzine .	$C^6 H^3$. Now, $2(C^6H^3)+2(CO^2)=C^{14}H^5O^2+O^2$
Benzamide .	$C^{14} H^5 O^2 + H^2 Az$
Benzimide .	$C^{14} H^5 O^2 + H_{\frac{1}{2}} Az^{\frac{1}{2}}$?
Nitrobenzide	$2(C^6 H^3) + Az O^4$
Sulphobenzide	$2(C^6 H^3) + S O^3$
Azotobenzide	$2(C^6 H^3) + Az$

SECTION II.—OF HYDRET OF BENZOYL.

This is the oil of bitter almonds, the properties and composition of which have been described at the beginning of this Chapter.

SECTION III.—OF BENZOIN.

The substance which Wöhler and Liebig have distinguished by the name of *benzoin*, was pointed out by Stange; but he merely mentioned its external characters. It has been noticed by some systematic writers under the name of *camphoride*, or *camphor of oil of bitter almonds*.

It is formed in certain circumstances in the oil of bitter almonds. MM. Wöhler and Liebig obtained it accidentally, while rectifying oil of bitter almonds with caustic potash, and they got a great quantity of it by leaving for some weeks oil of bitter almonds in contact with a concentrated solution of caustic potash. When benzoin is obtained in this manner, it has a yellow colour. By dissolving it in boiling alcohol, and treating it with animal charcoal, and then crystallizing it two or three times successively, we obtain it pure and colourless.

It forms transparent crystals in prisms, and having a splendent lustre. It has neither taste nor smell. It melts at 248° into a colourless liquid, which assumes the form of a crystalline solid body on cooling. When raised to a higher temperature it boils, and may be distilled over. It catches fire easily, and burns with a lively flame, emitting much smoke.

It is insoluble in cold, but slightly soluble in hot water, and falls down when the liquid cools in small crystalline needles. It is more soluble in hot than in cold alcohol. It is neither acted on by concentrated nitric acid, nor by a concentrated solution of potash.

Sulphuric acid dissolves it, and the solution has a violet-blue colour, which becomes gradually brown, and assumes, when heated, a deep green colour. Sulphurous acid is disengaged, and the whole assumes the colour and consistence of tar.

From the analysis of this substance by Wöhler and Liebig, it appears to be isomeric with the hydret of benzoyl. They obtained

Carbon	78
Hydrogen	5·7
Oxygen	16·3
	100·0*

Now, if the reader will turn to page 602 of this Chapter, and compare the analysis of hydret of benzoyl given there, with the preceding numbers, he will be at once satisfied, that the constituents of both are the same. Yet the properties of the two substances are exceedingly different.

When bromine is thrown on benzoin, the temperature rises, and a great deal of hydrobromic acid is disengaged. When we drive off this acid, and likewise any excess of bromine that has been added, we find the benzoin changed into a thick brown liquid, which has the smell of bromide of benzoyl, but does not become solid like that substance. Boiling water acts upon it exceedingly slowly. A boiling solution of caustic potash acts upon it with difficulty. When muriatic acid is added to this alkaline solution, crystals are deposited, the nature of which has not been ascertained.

Wöhler and Liebig attempted unsuccessfully to convert benzoin into oil of bitter almonds. When melted with hydrate of potash, it gave, as that oil does, benzoic acid, while hydrogen gas was disengaged. When treated with alcoholic solution of potash, it assumes a purple colour, and dissolves, and then separates again in a mass of crystalline plates. When treated with water, we obtain a milky liquid. If we heat it, and then allow it to cool, needle-form crystals are deposited, consisting of pure benzoin.

SECTION IV.—OF OXIDE OF BENZOYL, OR BENZOIC ACID.

This acid, which is benzoyl, combined with an atom of oxygen, has been described in a former Chapter.

SECTION V.—OF CHLORIDE OF BENZOYL.

When chlorine gas is passed through oil of almonds, or hydret of benzoyl, much heat is evolved, the gas is absorbed, and muriatic acid gas is disengaged. When the evolution of this gas is at an end, the liquid has a yellow colour from an excess of chlorine; but this excess is easily driven off by heat. The liquid is now pure chloride of benzoyl.

It is liquid and limpid like water. Its specific gravity is 1·196. It has a peculiar and very penetrating smell, which acts strongly on

* It was analyzed by M. Laurent with the same result. See Ann. de Chim. et de Phys. lix. 402.

the eyes, and has some analogy to that of horse-radish. Its boiling point is high. It takes fire, and burns with a clear flame with a green border, emitting much smoke.

When poured into water it falls to the bottom without dissolving. After remaining in water for a long time, or when the action is assisted by heat, it is decomposed into crystallized benzoic acid and muriatic acid. It undergoes the same change when long exposed to a moist atmosphere.

When chlorine gas is passed through a mixture of hydret of benzoyl and water, the oil disappears, and the water is filled with crystals of benzoic acid.

Chloride of benzoyl may be distilled off anhydrous barytes or chalk, without any alteration. When heated with an alkali and water, it gives immediately benzoate of the alkali, and chloride of the base of the alkali.

It was subjected to an analysis by Wöhler and Liebig, who obtained

Carbon	60·67 or	14 atoms =	10·5	or per cent.	59·58
Hydrogen	3·74 or	5 atoms =	0·625	— —	3·55
Oxygen	10·84 or	2 atoms =	2·0	— —	11·34
Chlorine	24·75 or	1 atom =	4·5	— —	25·53
	100		17·625		100·00

It is, therefore, benzoyl united with an atom of chlorine, or *chloride of benzoyl.*

This chloride, when assisted by heat, dissolves sulphur and phosphorus, and, on cooling, these bodies are again separated in crystals. It may be mixed in every proportion with bisulphuret of carbon. When placed in contact with perchloride of phosphorus it becomes hot, while protochloride of phosphorus is formed, together with an oily body, having a penetrating smell.

Chloride of benzoyl may be mixed in all proportions with alcohol. This mixture becomes gradually hot, and at last boils, while abundance of muriatic acid is disengaged. If we add water after all mutual action is at an end, a heavy oily substance separates, having an aromatic odour. If we wash it with water, and then distil it off chloride of calcium, we obtain it in a state of purity. This substance is benzoic ether, composed, as MM. Wöhler and Liebig have shown, of

1 atom benzoic acid $C^{14}\ H^{5}\ O^{3} + C^{4}\ H^{5}\ O$

or an atom of sulphuric ether. For they obtained, when they subjected it to analysis,

Carbon . .	72·529 = 18 atoms
Hydrogen . .	6·690 = 10 atoms
Oxygen . .	20·781 = 4 atoms
	100·000

SECTION VI.—OF BROMIDE OF BENZOYL.

This compound is formed when hydret of benzoyl is mixed with

bromine. Heat is evolved, and thick vapours of hydrobromic acid are exhaled. By heating the mixture, the excess of bromine and the hydrobromic acid are driven off, and bromide of benzoyl remains in a state of purity.

This bromide constitutes a soft, half liquid mass, composed of large crystalline plates, having a brownish colour. It melts when gently heated into a yellowish-brown liquid. Its smell is similar to that of the chloride of benzoyl; but much weaker, and slightly aromatic. In the air it smokes slightly; but the vapours become very copious if we heat it. It catches fire when exposed to a flame, and burns with a strong light, but emitting much smoke.

Water decomposes it slowly. When heated under water it assumes the form of a brownish oil. By long boiling it is decomposed into hydrobromic acid and crystallized benzoic acid. This shows us that it must be a compound of

1 atom benzoyl . .	$C^{14} H^5 O^2$
and 1 atom bromine. . .	Br

It dissolves readily in alcohol and ether without undergoing decomposition, and separates from them by evaporation in a mass of crystals.

SECTION VII.—OF IODIDE OF BENZOYL.

This compound cannot be formed by mixing hydret of benzoyl and iodine together; but it is readily obtained by heating a mixture of iodide of potassium and chloride of benzoyl. It distils over in the form of a brown liquid, which, on cooling, congeals into a crystalline mass, having the same brown colour, in consequence of an excess of iodine which it retains in solution. When pure it is colourless, crystallizes in tables, melts easily; but always undergoes partial decomposition, giving out iodine. Its smell, its action on water and alcohol, and its combustibility, are similar to those of the preceding compounds.

SECTION VIII.—OF SULPHURET OF BENZOYL.

This compound is obtained when we distil a mixture of chloride of benzoyl and sulphuret of lead in fine powder. We get it under the form of an oil which congeals into a soft, yellow, and crystalline mass. It has a disagreeable odour, which puts one in mind of that of sulphur. It does not seem to be decomposed when boiled with water. When treated with a boiling solution of caustic potash, it is very slowly converted into benzoic acid and sulphuret of potassium. It is inflammable, and burns with a strong flame, giving off much smoke, and forming sulphurous acid. Alcohol does not decompose it.

SECTION IX.—OF CYANODIDE OF BENZOYL.

Hydret of benzoyl is capable of dissolving a certain quantity of cyanogen, and of assuming the smell of that gas; but it can be driven off by heat without any decomposition. If we distil chloride

of benzoyl over cyanet of mercury, a true cyanet of benzoyl passes over in the form of a golden-yellow oil, while dichloride of mercury remains behind in the retort.

Cyanodide of benzoyl, when rectified and pure, is a colourless liquid; but it speedily assumes a yellow colour. Its smell, which is strong and penetrating, excites tears. It has a slight analogy with that of oil of cinnamon. Its taste is sweetish, but acrid, leaving in the mouth an impresion of prussic acid.

It is heavier than water, and when poured into that liquid falls to the bottom like oil, and is speedily changed into benzoic acid and hydrocyanic acid. If we leave a drop of it spread upon the surface of water, we find it next day changed into crystals of benzoic acid. When boiled with water it changes very rapidly into benzoic and hydrocyanic acids. It is combustible, burning with a white flame, and giving out much smoke.

SECTION X.—OF BENZONE.

This name has been applied by M. Peligot to a substance obtained when benzoate of lime is distilled. The term was applied from the analogy between *benzone* and *acetone*, the name given by Dumas and Liebig to the liquid formerly called *pyroacetic spirit*.

M. Peligot observed,* that when crystallized benzoate of lime is distilled in a retort, raised almost to a red heat, there passes over into the receiver a brown heavy oil, while carbonate of lime remains behind in the retort. This oil contains at once benzone, bicarburet of hydrogen, and naphthalin. To get rid of the bicarburet of hydrogen, the oil is exposed for a long time to the heat of the water-bath. The bicarburet of hydrogen, which boils at 187°, is gradually disengaged. After this the oil is distilled over the naked fire. We obtain first water, then an oil, deeper coloured than the product of the distillation of the benzoate of lime, but equally heavy, and boiling about the temperature of 482°. It consists of a mixture of benzone and naphthalin. When we cool it down by means of a freezing mixture to —4°, and keep it for some time in that low temperature, the naphthalin crystallizes, and the benzone, which remains liquid, is easily drawn off by a sucker. Peligot is of opinion that the benzone would be the only product if the benzoate of lime were anhydrous, and the heat never raised above the proper point, so that benzoic acid would be resolved into benzone and carbonic acid.

Benzone is a thick oil, colourless when pure, but usually amber coloured. It has a peculiar, but not disagreeable smell. Its specific gravity is less than that of water, and its boiling point not under 482°. It is not acted on by nitric acid, or by potash; but sulphuric acid renders it brown, and decomposes it. When put into chlorine gas and exposed to the action of light, muriatic acid is formed, and crystals make their appearance which have not yet been subjected to examination.

* Ann. de Chim. et de Phys. lvi. 59.

M. Peligot subjected benzone to an analysis by means of oxide of copper, and obtained

Carbon	87·35 or	13 atoms	= 9·75	or per cent.	84·72
Hydrogen	5·65 or	5 atoms	= 0·625	— —	5·49
Oxygen	7·00 or	1 atom	= 1	— —	8·79
			11·375		100·00

These numbers do not agree very closely with the analysis, but they must be the true ones, if benzoic acid be decomposed into benzone and carbonic acid. For

Benzoic acid, is . .	$C^{14} H^5 O^3$
And subtracting carbonic acid	$C \quad O^2$
Remains for benzone .	$C^{13} H^5 O$

SECTION XI.—OF BENZIN.

Mitscherlich observed, in 1833,* that when benzoic acid is mixed with 3 or 4 times its weight of slacked lime, and the mixture distilled, we obtain pure bicarburetted hydrogen, and nothing else, while the lime is converted into a carbonate. To the bicarburet of hydrogen, thus obtained, he has given the name of *benzin*.†

Benzin is a limpid and colourless liquid. It has a peculiar smell, and its specific gravity is 0·83. It boils at 187°, and when surrounded with ice congeals into a crystalline mass, which melts when heated to 44°½. It dissolves readily in alcohol and ether, but in very small quantity in water, though it communicates to that liquid a strong smell. It is not dissolved nor altered by sulphuric acid, even though distilled over with it. Muriatic acid and the other powerful acids are equally inert. Chlorine gas has little action on it in the dark; but when light is admitted, thick clouds of muriatic acid appear, and crystals, together with a soft matter, are formed. The soft substance dissolves easily in ether, while the crystals are much less soluble, so that in this way they may be separated from each other.

Bromine decomposes benzin. But iodine dissolves in it without decomposing it. Mitscherlich analyzed it, and found the constituents

Carbon	91·3 or	2 atoms	= 1·5	or per cent.	91·38
Hydrogen	7·7 or	1 atom	= 0·125	— —	7·62
			1·625		99·00

It is clear that the benzin of Mitscherlich is the same with the bicarburet of hydrogen of Faraday,‡ both in its properties and composition. He found the density of its vapour to be 2·77. It is obvious from this, that it is composed of

* Ann. de Chim. et de Phys. lv. 42.

† Altered by Liebig to Benzol. See Ann. der Pharmacie, ix. 43.

‡ Described in the Chemistry of Inorganic Bodies, i. 202.

	Sp. gravity.
6 volumes carbon vapour .	= 2·5000
3 volumes hydrogen gas .	= 0·2083
	2·7083

Condensed into 1 volume. So that it is a compound of

6 atoms carbon . . .	= 4·5
3 atoms hydrogen . .	= 0·375
And its atomic weight is	4·875

Crystallized benzoic acid contains an atom of water, and is, therefore, ... $C^{14}\ H^{6}\ O^{4}$

It may be resolved into

2 atoms benzin . .	$C^{12}\ H^{6}$
2 atoms carbon acid .	$C^{2}\ \ O^{4}$
	$C^{14}\ H^{6}\ O^{4}$

Thus we have a new way in which benzoic acid may be resolved into two new and simpler substances.

SECTION XII.—OF NITROBENZIDE.

This is a name given by Mitscherlich, to a substance formed when nitric acid is made to act upon his *benzin*.

Benzin and nitric acid of moderate strength, have so little action on each other, that they may be distilled together without altering the nature of the benzin. But when benzin is heated with fuming nitric acid, action takes place with the disengagement of heat. The benzin should be added to the hot acid in small quantities at a time. The resulting compound dissolves completely in the hot acid; but when the liquid cools, a portion separates and swims upon the surface. When water is added, this portion falls to the bottom of the liquid, because it is heavier than water. If we wash this substance and distil it again, we obtain it in a state of purity. It is the nitrobenzide of Mitscherlich.

It is a light yellow liquid, having a very sweet taste, and a peculiar odour, intermediate between that of oil of bitter almonds, and oil of cinnamon. Its specific gravity at 59° is 1·209. It boils at 415°, and may be distilled over without alteration. At 37°½ it becomes solid, and crystalline needles make their appearance in it.

It may be distilled with nitric acid without any alteration. When mixed with dilute nitric acid, it may also be distilled over unaltered, if the temperature be sufficiently high. But concentrated sulphuric acid, when boiling hot, decomposes it, with the disengagement of sulphurous acid. Chlorine and bromine, have no action on it in a liquid state. But when passed through a red hot tube along with chlorine, muriatic acid is formed. When heated with potassium, it detonates and breaks the vessel. An aqueous solution of potash has little action on it. An alcoholic solution of potash does not act at the ordinary temperature, but when boiled with it, the liquid assumes

a blood-red colour. When distilled it gives a red matter, which is solid at the common temperature of the atmosphere. Ammonia does not act upon nitrobenzide.

The mean of two analyses, by M. Mitscherlich, gave for its constituents

Carbon	58·53	or 12 atoms	= 9	or per cent.		58·54
Hydrogen	4·08	or 5 atoms	= 0·625	—	—	4·06
Azote	11·02	or 1 atom	= 1·75	—	—	11·38
Oxygen	25·99	or 4 atoms	= 4·00	—	—	26·02
			15·375			100·00

It is probable that the true quantity of hydrogen is 6 atoms. In that case, it would be a compound of 2 atoms benzin, and 1 atom of nitrous acid.

For 2 atoms benzin are . . .	C^{12} H^6
1 atom nitrous acid . . .	Az O^4
	C^{12} H^6 Az O^4

The specific gravity of its vapour was found by Mitscherlich to be 4·40, or from that to 4·35. Now if we consider it as consisting of one volume of benzin vapour, and half a volume of nitrous acid vapour condensed into one volume, we have

	Sp. gravity.
6 volumes carbon vapour .	= 2·6
3 volumes hydrogen gas .	= 0·2083
½ volume azotic gas . .	= 0·4861
1 volume oxygen gas .	= 1·1111
	4·4055

A specific gravity almost coinciding with that found by Mitscherlich.*

SECTION XIII.—OF SULPHOBENZIDE.

When small quantities of benzin are added to the sulphuric acid of Nordhausen, as long as it continues to be dissolved, and then water is poured into the liquid, there separates a crystalline substance, so small in quantity that it scarcely amounts to 2 per cent. of the benzin employed. If we saturate the liquid with carbonate of barytes, and throw down the barytes by sulphate of copper, and concentrate, we obtain crystals composed of oxide of copper, and the acid of the soluble salt of barytes; that is to say, of *benzosulphate of copper*.

If, instead of this, we place benzin in contact with anhydrous sulphuric acid, the acid is not decomposed, and there is consequently no disengagement of sulphurous acid. We obtain a thick liquid which dissolves entirely in a little water. But if we mix it with a great deal of water, there separates a much greater quantity of the crystalline substance, as it amounts to 5 or 6 per cent. of the benzin employed.

* Mitscherlich; Poggendorf's Annalen, xxxi. 225.

If we saturate the acid with barytes, and decompose the new salt by means of sulphate of copper, we sometimes on evaporating, this liquid, obtain none, sometimes only a little of benzosulphate of copper; but a crystalline powder separates when we evaporate to dryness. We obtain the same substance, when we treat the crystalline matter with hot and concentrated sulphuric acid.

The crystalline substance being but little soluble in water, may be completely freed from all excess of acid by washing. To purify it completely, we have only to dissolve it in ether, let it crystallize, and distil over the crystals.

It is soluble in alcohol and ether, and may be obtained from these solutions in regular crystals. At 212° it melts into a transparent and colourless liquid, and boils at a temperature between the boiling points of mercury and sulphur.

It is colourless and destitute of smell. It is insoluble in alkalies; but dissolves in acids, and is precipitated by water. When heated with sulphuric acid, it combines with it and forms a peculiar acid, which gives a soluble salt with barytes. The other acids do not alter it. It detonates when heated with saltpetre or chlorate of potash. At the ordinary temperature, chlorine and bromine have no action on it, but when it is heated to the boiling point, these two substances decompose it, and chloride of benzin is formed.

Mitscherlich analyzed this substance, and found the constituents:

Carbon	66·18	or 12 atoms	= 9
Hydrogen	4·55	or 5 atoms	= 0·625
Sulphuric acid	35·42	or 1 atom	= 5
	106·15		14·625

Or probably 2 atoms of benzin combined with 1 atom of sulphuric acid.*

SECTION XIV.—OF AZOTOBENZIDE.

This name has been given by Mitscherlich to a substance obtained by distilling a mixture of nitrobenzide and lime. But the best way of forming it is to dissolve nitrobenzide in alcohol, and mix it with an alcoholic solution of potash. When heat is applied to this mixture, a rapid action takes place. A salt of potash is formed, different from saltpetre, and a compound, upon which a farther addition of potash has no action. When this substance, which is red, is distilled, a red liquid passes over, which, on cooling, shoots into large crystals. If these crystals be dried upon blotting paper, dissolved in ether, and crystallized again, they constitute *azotobenzide* in a state of purity.

It dissolves readily in ether and alcohol, and easily crystallizes from both solutions. Boiling water dissolves it very sparingly, yet it acquires a red colour, and becomes muddy on cooling. It is very little soluble in ammonia, concentrated potash ley, or strong muriatic

* Poggendorf's Annalen, xxxi. 628.

acid. It dissolves in concentrated nitric and sulphuric acids, and is again precipitated from them by water. When the sulphuric acid solution is heated, decomposition takes place, charcoal being deposited, and sulphurous acid given out. It may be distilled unaltered from potash ley or quick lime.

It melts when heated to 149°, boils at 379°, and may be distilled over without decomposition. It was subjected to an analysis by Mitscherlich, who obtained

Carbon	79·16 or	12 atoms =	9	or per cent.	79·12
Hydrogen	5·45 or	5 atoms =	0·625	— —	5·49
Azote	14·95 or	1 atom =	1·75	— —	15·39
	99·56		11·375		100·00

So that it differs from nitrobenzin, in wanting the 4 atoms of oxygen which exists in that substance. It is probably a compound of 2 atoms of benzin and 1 atom of azote.*

CHAPTER III.

OF SPIROIL AND ITS COMPOUNDS.

Spiroil is the supposed base of the volatile oil extracted from the flowers of the *spiræa ulmaria*, by M. Pagenstecher of Berne, who determined its properties, and showed that it possessed acid characters. M. Löwig of Zurich has analyzed this oil, and shown that it is a compound of C^{12} H^5 O^4, with an atom of hydrogen. This compound, C^{12} H^5 O^4, has not been obtained in a separate state, but it has been combined with oxygen, chlorine, bromine, iodine, and hydrogen, and shown to form definite compounds with each. To this hypothetical base Löwig has given the name of spiroil.† The compounds which it forms, so far as they have been examined, will be described in the following Sections:—

SECTION I.—OF HYDROSPIROILIC ACID.

The volatile oil of *spiræa ulmaria*, or hydrospiroilic acid, may be obtained by distilling the fresh flowers of the plant along with water. A quantity of water is allowed to come over, about equal to the weight of the flowers employed. The product of this distillation is distilled anew, till about $\frac{1}{3}$th part of it pass into the receiver. We obtain, in this way, a strong aqueous solution of the oil, and a small quantity of the oil itself.

It is heavier than water, has a light-yellow colour, and has the same smell as the flowers of the *spiræa ulmaria*, only much stronger. It may be mixed in all proportions with alcohol and ether. It is

* Mitscherlich; Poggendorf's Annalen, xxxii. 225.

† Poggendorf's Annalen, xxxvi. 283.

soluble also in water, but less so than in the two other liquids. Its taste is hot and acrid. Litmus paper is rendered first green, and then white, by the vapour of the oil, while distilling. Tincture of litmus is rendered first red by the aqueous solution of the oil, then whitened, retaining a slight shade of green. It is combustible, and burns with a lively flame, giving out smoke.

When this oil is passed through a red hot tube, filled with fragments of iron, we obtain no ammonia nor hydrocyanic acid; nor is any sulphuret of iron formed. It may be evaporated completely without undergoing any alteration. It becomes solid when cooled down to 4°. It boils at 185°, at which temperature it may be distilled over without leaving any residue.

It combines readily with the alkalies and alkaline earths, and forms with them salts insoluble, or but little soluble.

Concentrated sulphuric acid chars it. Chlorine and bromine immediately decompose it; muriatic acid or hydrobromic acid being formed, and chloride or bromide of spiroil. Nitric acid, if not too strong, converts it into spiroilic acid. But concentrated nitric acid changes it into a yellow butyraceous mass, very volatile, and having a bitter taste.

The anhydrous oil was analyzed by Löwig in the usual way, by means of oxide of copper. He obtained

Carbon	65·26 or	12 atoms	= 9	or per cent.	65·45
Hydrogen	5·55 or	6 atoms	= 0·75	— —	5·46
Oxygen	29·19 or	4 atoms	= 4	— —	29·09
	100·00		13·75		100

If we agitate hydrated oxide of copper in an aqueous solution of the oil, taking care that there be an excess of oil, we obtain a green-coloured matter, which may be dried in the temperature of 320°, without undergoing any change. For the oil may be still separated from it unaltered by means of an acid. M. Löwig subjected this compound to analysis, and obtained

Carbon	50·78 or	12 atoms	= 9	or per cent.	51·06
Hydrogen	3·44 or	5 atoms	= 0·625	— —	3·54
Oxygen	23·09 or	4 atoms	= 4	— —	22·70
Copper	22·69 or	1 atom	= 4	— —	22·70
	100·00		17·625		100

If we compare this constitution with that of the hydrospiroilic acid, we perceive that the only difference between the two is the substitution of an atom of copper in the latter compound for an atom of hydrogen in the former. This is what has induced M. Löwig to consider the acid or oil as a compound of 1 atom hydrogen with the compound base C^{12} H^{5} O^{4}, to which he has given the name of *spiroil*.

As a farther corroboration of the justness of his views, M. Löwig made the following experiment:—Hydrospiroilic acid was placed in contact with potassium over mercury. The temperature rose a

little, and hydrogen gas was evolved, while a spiroilide of potassium was formed. When this spiroilide is treated with muriatic acid, we obtain chloride of potassium, and the oil is separated unaltered. When this experiment is made at the common temperature of the atmosphere, the action is gentle; but if we apply heat, it is so accelerated, that flame is produced. No charcoal is deposited, and the hydrogen is perfectly pure. If the oil employed be not quite dry, a little hydrogen is evolved the instant the potassium comes in contact with it, but this disengagement speedily stops. If we now apply heat, the disengagement of hydrogen begins again, and is discharged in the same way as when anhydrous oil is employed.

Let us now attend to the characters of the salts formed by the combination of hydrospiroilic acid with the bases.

1. *Hydrospiroilate of ammonia.* If we pour a concentrated solution of ammonia upon hydrospiroilic acid, the temperature speedily rises, and the whole becomes a solid mass of hydrospiroilate of ammonia. By washing this salt with alcohol, we may deprive it of water, and of any excess of acid that it may contain. It has a weak aromatic smell, analogous to that of the rose. It has a yellow colour, and is destitute of taste. It is almost insoluble in water, and but little soluble in cold hydrous alcohol. But absolute alcohol dissolves it in considerable quantity, both cold and hot. When the boiling alcoholic solution is allowed to cool, the salt crystallizes in fine transparent needles, usually collected in tufts, and having a light yellow colour. When this salt is kept moist in close vessels, it gradually undergoes decomposition. It becomes first black, then semifluid, ammonia is disengaged, and a strong smell of roses is perceptible.

When heated to 212°, it undergoes no alteration. At 239°, it melts like wax, and is volatilized unaltered in a yellow vapour, when heated a few degrees above its melting point. Acids decompose it, uniting with the ammonia, while the oil is separated unaltered. M. Löwig analyzed it, and found its constituents to be

Ammonia . . .	13·52	or 2·125
Hydrospiroilic acid .	86·48	or 13·59
	100·00	

According to this analysis, the atomic weight of hydrospiroilic acid is 13·59. Now, this approaches very near to 13·75, which is the atomic weight deduced from the direct analysis of the oil. It is obvious that the salt is a compound of 1 atom acid and 1 atom ammonia.

2. *Spiroilide of potassium.* This compound is obtained when potassium is placed in contact with hydrospiroilic acid, and a gentle heat applied. Or it may be formed by placing in contact aqueous solutions of the acid, and of potash. It is with difficulty soluble in water. If we evaporate its solution slowly, we obtain small prismatic crystals, of a straw-yellow colour. When exposed to the air it is decomposed, attracting moisture and carbonic acid. In dry ves-

sels it may be kept a long time without decomposition. During its decomposition the smell of roses becomes manifest. At last nothing remains but carbonate of potash.

This spiroilide is composed of

1 atom spiroil . . .	13·625
1 atom potassium . . .	5
	18·625

3. *Spiroilides of sodium*, *calcium*, and *barium*, resemble closely the spiroilide of potassium, only the two last are less soluble in water.

4. *Spiroilide of magnesium* may be formed by agitating together the aqueous solution of hydrospiroilic acid and hydrate of magnesia. It is a light yellow almost insoluble powder.

5. *Spiroilide of iron.* Protochloride of iron is not altered by an aqueous solution of hydrospiroilic acid. When ammonia is added, a dark violet-blue precipitate falls.

6. *Sesquispiroilide of iron.* Perchloride of iron, when mixed with the aqueous solution of hydrospiroilic acid, gives it a fine dark-red cherry-red colour, without occasioning any precipitate. If we expose the mixture to the air, it gradually loses its red colour, and there remains a pure solution of sesquichloride of iron. If we add a little more solution of hydrospiroilic acid, the cherry-red colour again appears.

7. *Dispiroilide of copper.* Dichloride of copper is not altered by an aqueous solution of the oil. A small addition of ammonia throws down a light brown precipitate.

8. *Spiroilide of copper.* We obtain this compound when we agitate the aqueous solution of the oil with hydrate of copper. The hydrate speedily loses its blue colour, and becomes green. If we mix a solution of sulphate of copper with spiroilide of potassium, a bulky precipitate falls, which separates very slowly, and puts on an imperfect appearance of crystals.

9. *Spiroilide of zinc.* When oxide of zinc is agitated with a solution of the oil in water, it rapidly combines with it. The water assumes a yellow colour. If we evaporate under the air pump, we obtain a yellow powder. Sesquichloride of iron renders the liquid cherry-red.

10. *Spiroilide of lead.* Pure oxide of lead does not form a spiroilide when placed in contact with an aqueous solution of hydrospiroilic acid. But the hydrated oxide, when agitated with that liquid, is converted into small shining scales, constituting a light yellow powder of spiroilide of lead.

11. *Spiroilide of mercury.* Red oxide of mercury does not form a spiroilide when agitated with the aqueous solution of the oil. But we obtain it when we mix together concentrated solutions of corrosive sublimate and hydrospiroidate of ammonia. The precipitate is bulky, composed of flocks, and has a light straw-yellow colour.

12. *Spiroilide of silver.* Oxide of silver dissolves partially in the aqueous solution of the oil. The solution has a yellow colour, and

a bitter metallic taste. By evaporation *in vacuo* we obtain a blackish-brown residue, which detonates at the flame of a candle, leaving metallic silver. The portion of oxide not dissolved has also assumed the same blackish-brown colour, and possesses the same detonating quality.

Most of these spiroilides may be formed also by double decomposition. The solutions must be very concentrated, and the spiroilide must be insoluble, or nearly so.

SECTION II.—OF CHLORIDE OF SPIROIL.

We obtain this compound when we decompose hydrospiroilic acid by chlorine. Dry chlorine gas is passed slowly over the anhydrous acid, taking care not to apply any artificial heat. Muriatic acid is disengaged, and if the current of chlorine passes slowly, the temperature is but little increased. The process must be continued till the disengagement of muriatic acid ceases. The acid is completely converted into a white mass, evidently crystalline. This matter is to be sublimed by a very gentle heat. It is then pure chloride of spiroil.

It is in brilliant crystalline white plates, which melt when very slightly heated. When strongly heated the fused mass becomes deep-coloured, and there remains a minute quantity of charcoal. Nothing else passes over but muriatic acid and chloride of spiroil.

This chloride has a peculiar smell, slightly aromatic, and yet having considerable resemblance to dilute hydrocyanic acid. Its boiling point is not higher than that of water. It is combustible, and burns with a green flame, giving out smoke.

It is insoluble in water. When boiled with that liquid it is volatilized completely, and no muriatic acid is formed. It is not altered by the atmosphere, whether moist or dry.

It is very soluble in alcohol and ether. The alcoholic solution gives, with acetate of copper, a greenish-yellow precipitate. It precipitates the salts of lead yellow. Barytes water separates the spiroil from the liquid, forming with it a yellow precipitate.

With the alkalies it forms compounds, which have a yellow colour, are neutral, little soluble, and give a blue-black colour to the persalts of iron. It seems to combine with the metallic oxides and alkalies, without undergoing any change, for we obtain it unaltered when these compounds are decomposed by an acid.

This chloride, after being freed from water by fusion, was analyzed by M. Löwig, who obtained

Carbon	49·44 or	12 atoms	= 9	or per cent.	49·65
Hydrogen	3·36 or	5 atoms	= 0·625	— —	3·45
Oyxgen	23·81 or	4 atoms	= 4	— —	22·07
Chlorine	23·39 or	1 atom	= 4·5	— —	24·83
	100·00		18·125		100·00

This is obviously a compound of 1 atom spiroil, C^{12} H^{5} O^{4}, and 1 atom chlorine.

SECTION III.—OF BROMIDE OF SPIROIL.

The easiest method of obtaining this compound, is to pour bromine upon hydrospiroilic acid in a glass vessel. Hydrobromic acid is disengaged, the temperature rises and the mixture is converted into a white solid crystalline mass. We obtain it also by agitating together aqueous solutions of the acid and of bromine. It precipitates in white flocks to the bottom of the vessel. The supernatant liquid is colourless and without smell, and contains hydrobromic acid. To free it from all adhering bromine and hydrospiroilic acid it must be melted over the water-bath, and kept in fusion till it ceases to give out acid vapours.

The properties of this bromide are quite similar to those of the chloride; excepting that it requires a higher temperature to melt it and that its alkaline salts are less soluble.

It was carefully analyzed by M. Löwig, who obtained

Carbon	38·34 or 12 atoms =	9	or per cent.	38·10
Hydrogen	2·76 or 5 atoms =	0·625	— —	2·65
Oxygen	18·44 or 4 atoms =	4	— —	16·93
Bromine	40·46 or 1 atom =	10	— —	42·32
	100·00	23·625		100·00

Thus the bromide is obviously a compound of 1 atom spiroil, $C^{12} H^5 O^4$, and 1 atom bromine.

SECTION IV.—OF IODIDE OF SPIROIL.

Hydrospiroilic acid dissolves iodine very readily, and forms with it a liquid of a blackish-brown colour; but we do not perceive any formation of hydriodic acid. We obtain an iodide of spiroil, if we distil the chloride or bromide of spiroil with iodide of potassium. A double decomposition takes place when the two substances are mixed, and when heat is applied the iodide of spiroil sublimes. It is solid, has a deep-brown colour, is easily fusible, and, as far as its solubility in water, ether, and alcohol, and its combinations with bases have been examined, they are quite analogous to the same characters in the chloride and bromide.

SECTION V.—OF SPIROILIC ACID.

This acid was discovered by M. Löwig, by treating the hydrospiroilic acid, described in a former Section, with nitric acid. The nitric acid should not be strong, and the heat applied should be moderate, and care should be taken not to apply the nitric acid in excess. The oil is changed into a solid crystalline mass, while vapours of nitrous gas, without any mixture of carbonic acid, are disengaged. The substance thus obtained is spiroilic acid.*

It has scarcely any smell. At first it seems tasteless; but we

* Poggendorf's Annalen, xxxvi. 394.

experience soon a violent feeling of irritation in the pharynx, with an inclination to cough.

Spiroilic acid is fusible, and shows a great tendency to crystallize when it passes from a liquid to a solid state. It may be sublimed in close vessels, but it is partly decomposed, and some charry matter is left behind. It has a colour slightly yellow. When exposed to the air it absorbs moisture, and becomes of a deep-yellow colour.

It dissolves readily in alcohol and ether; but is very little soluble in water. The solution gives a permanently-yellow colour to the skin and nails. It gives a deep-yellow colour to litmus paper; but we do not perceive any red colour produced. When the alcoholic solution of spiroilic acid is left to spontaneous evaporation, the acid crystallizes in fine transparent prisms, having a golden yellow colour.

It was analyzed by M. Löwig, who obtained

Carbon	50·23 or 12 atoms	= 9	or per cent.	51·06
Hydrogen	3·51 or 5 atoms	= 0·625	— —	3·55
Oxygen	46·26 or 8 atoms	= 8	— —	45·39
	100·00	17·625		100·00

Thus we see that, by the action of the nitric acid, 1 atom of hydrogen has been withdrawn from the hydrospiroilic acid, and 4 atoms of oxygen substituted in its place. Spiroilic acid consequently is a compound of 1 atom spiroil, $C^{12} H^5 O^4$, and 4 atoms of oxygen.

When spiroilic acid is slightly heated in contact with potassium, a very bright flame is produced, and the vessels are shattered in pieces. Even when an excess of potassium is used, the acid is but partially decomposed, a spongy charcoal separates, and there are formed spiroilate of potash, and spiroide of potassium.

The alkalies combine with spiroilic acid. The salts are yellow, and are obtained in small crystals by evaporating the aqueous solution of the salts. If we dissolve spiroilic acid in ether, and agitate the solution with potash or soda ley, the acid is taken from the ether and combines with the alkali.

The alkaline spiroilates are soluble in alcohol. When spiroilic acid is saturated with ammonia we obtain a deep-red liquid. When evaporated to dryness, it leaves a yellow residue which contains ammonia. This spiroilate is decomposed at a high temperature in close vessels: a little ammonia is disengaged, and a little oily matter passes into the receiver.

The aqueous solution of spiroilate of soda, gives a yellow precipitate with acetate of lead, and a green with the salts of copper.

When the spiroilates are heated in the air, they fulminate, leaving the base either pure or in the state of a carbonate and a charcoal, which discolours powerfully. When they are mixed with a combustible body, as sulphur, and heated, they detonate.

Fuming nitric acid acts violently on spiroilic acid. A yellow bitter tasted substance is produced, which gives a yellow colour to the saliva, the skin and the nails. It is fusible, and may be distilled over, and has a strong smell of fresh butter. Oxalic acid is formed at the same time with this yellow substance.

CHAPTER IV.

OF SUGARS.

The term *sugar*, in common language, is applied to various substances, all of which are characterized by their sweet taste. In this Chapter I shall give an account of nine different substances, all of which have a sweet taste; but scarcely any other property in common.

SECTION I.—OF COMMON SUGAR.

Sugar, which at present constitutes so important an article in the food of all civilized nations, seems to have been known at a very early period to the inhabitants of India and China. But Europe probably is indebted for its acquaintance with it to the conquests of Alexander the Great. The word *saccharum* occurs in Pliny* and Dioscorides.† They describe it as a white brittle solid, which exudes spontaneously from a species of reed. From this statement (if accurate) it would seem, that the sugar known to the ancients was not the same with our sugar. But their account is so imperfect that little can be collected from it.‡ For ages after its introduction into the west, it was used only as a medicine. But its consumption gradually increased; and during the crusades the Venetians, who brought it from the east, and distributed it to the northern parts of Europe, carried on a lucrative commerce with sugar. It was not till after the discovery of America, and the introduction of the sugar cane into the West Indies by the Spaniards, that its use in Europe as an article of food became general.§

Sugar was formerly manufactured in the southern parts of Europe; but at present almost the whole of our sugar is produced in the East and West Indies. The plant from which it is produced is the *arundo saccharifera*, or *sugar cane*. Other plants indeed contain it; but not in such abundance. In North America, however, it is extracted from the *acer saccharinum*, or *sugar maple*, but in too small quantity for exportation.

* Plinii Hist. Nat. lib. xii. c. 8.

† De Medica Materia, lib. ii. c. 104, or, in some copies, c. 74.

‡ See Beckmann's Historia Sacchari, Commentationes Soc. Reg. Gottingensis, 1782, vol. v. p. 56.

§ See Falconer's *Sketch of the History of Sugar*, Manchester Memoirs, iv. 291; and Mosley's History of Sugar.

During the war between Bonaparte and Great Britain, the extraction of sugar from the *beet* root was introduced into France. This manufacture still continues. In the year 1827, the quantity of beet sugar made in France was 2,650,000 lbs.*

1. The method of making sugar practised in Indostan is exceedingly simple, and requires little or no expensive apparatus. The soil chosen is a rich vegetable mould, in such a situation that it can be easily watered from the river. About the end of May, when the soil is reduced to the state of soft mud, either by rain or artificial watering, slips of the cane, containing one or two joints, are planted in rows about four feet from row to row, and eighteen inches asunder in the rows. When they have grown to the height of two or three inches, the earth round them is loosened. In August small trenches are cut through the field to drain off the rain, if the season prove too rainy; and to water the plants, if the season prove too dry. From three to six canes spring from each slip set. When they are about three feet high, the lower leaves of each cane are carefully wrapped round it; and then the whole belonging to each slip are tied to a strong bamboo eight or ten feet high, and stuck into the earth in the middle of them. They are cut in January and February, about nine months after the time of planting. They have now reached the height of eight or ten feet, and the naked cane is from an inch to an inch and a quarter in diameter. They have not flowered. When this happens, the juice loses much of its sweetness. The newly cut canes are put through the rollers of a mill, and their juice collected into large iron boilers, where it is boiled down smartly to a proper consistence, the scum being carelessly taken off. The fire is then withdrawn, and the liquid by cooling becomes thick. It is then stirred about with sticks till it begins to take the form of sugar, when it is put in mats made of the leaves of the palmira tree (*borassus flabelliformis*), and the stirring continued till it is cold.† This process yields a *raw* or *powdered* sugar; but it is clammy, and apt to attract moisture from the atmosphere, because the acids in the juice have not been removed. By the addition of quick lime to the juice in the proportion of about three spoonfuls to every 14 gallons, the sugar loses this property. The impure sugar prepared by this method is called *jagary*. Every three quarts of juice, or every six pounds, yield about one pound of sugar. From an acre of ground about 5000 pounds of sugar, and consequently about 30,000 pounds of juice are obtained.

2. In the West India islands the raising of sugar is much more expensive, and the produce much less, owing to the high price of labour; or, which is the same thing, to the nature of the labourers, and to the inferiority of the soil. The juice extracted by passing the cane twice between iron rollers is received in a leaden bed, and

* Ann. de Chim. et de Phys. xxxvii. 53.

† See Dr Roxburgh's Account of the Hindoo Method of Cultivating the Sugar Cane, Repertory, ii. 425, Second Series; and Tennant's Indian Recreations, ii. 31.

thence conducted into a *receiver*. Here it cannot be allowed to stand above 20 minutes without beginning to ferment. Therefore, as soon as collected, it is run into a flat copper caldron called a *clarifier*, capable of holding 400 gallons or more. Here it is mixed with a quantity of lime. The maximum used is a pint of lime to every hundred gallons; but in general much less will serve. Fire is immediately applied, and the juice heated to the temperature of 140°. The fire is then extinguished. A thick viscid scum forms upon the top, which remains unbroken, and the clear liquid is drawn off from under it by a cock or syphon, and introduced into a large copper boiler. Here it is boiled briskly; the scum, as it forms, being continually removed by large skimmers. When the bulk of the liquid is sufficiently diminished, it is introduced into a second boiler, and the boiling and skimming continued as before; lime-water being sometimes added, if the liquid does not appear clear. From the second copper it passes into a third; and from that to a fourth, where the very same process is continued. This last copper is called the *teache*. When by continued evaporation it has become sufficiently concentrated, which is judged of by its viscidity, it is withdrawn from the fire, and introduced into the *cooler*. This is a wooden vessel about 11 inches deep, seven feet long, and from five to six wide. As it cools it crystallizes or *grains*, forming an irregular mass separated from the uncrystallized syrup or *melasses*. From the cooler it is taken and put into empty hogsheads, having holes in the bottom; through each hole the stalk of a plaintain leaf is thrust, long enough to rise above the top of the hogshead. Through these holes the melasses drain into a receiver. In about three weeks the sugar becomes tolerably dry and fair, and the process is finished. The sugar in this state is sent to Britain, under the name of *muscovado* or *raw* sugar.* A gallon of the raw juice yields at an average about a pound of raw sugar.†

In the French West India islands the process is somewhat different. From the cooler the inspissated juice is poured into conical-shaped pots with the point undermost. As soon as it has become solid, a plug is withdrawn from the point of the cone, and the melasses suffered to drain. When no more will drop, a stratum of clay, moistened with water, is laid upon the top of the sugar. The water from this, slowly penetrating the sugar, carries down the remains of the melasses. Sugar treated in this way, is called *clayed* sugar. The process is said to have been discovered by accident. A hen having her feet dirty had gone over a pot of sugar, and the sugar under her tread was found whiter than elsewhere. By claying, the sugar loses about $\frac{1}{3}$d of its weight; but a considerable portion of the loss may be obtained by boiling down the juice that runs off. The process is not considered as so profitable in the British islands as the one which is usually followed.‡

3. In North America the farmers procure sugar for their own use

* Edward's History of the West Indies, ii. 222. † Ibid. p. 224.
‡ Ibid. ii. 232.

by a still simpler process, from the sap of the *acer saccharinum*, or *sugar maple tree*, which abounds in the woods. It reaches maturity in about 20 years, and is then from two to three feet in diameter. In February, March, and April, the tree is bored with an auger to the depth of about $\frac{3}{4}$ths of an inch, and in an ascending direction. The hole is then deepened to two inches. A wooden spout is introduced into the hole to direct the flow. The sap flows from four to six weeks. When it ceases on the south side, the north side is bored. This process does not injure the tree; but on the contrary improves it. An ordinary tree yields, in good seasons, from 20 to 30 gallons of sap; from which are made from five to six pounds of sugar; or every forty pounds of sap yield about a pound of sugar; so that it is not $\frac{1}{6}$th so rich as the East India sugar cane.

The sap ought never to be kept longer than twenty-four hours after it is procured from the tree. It is improved by straining through a cloth. It is put into large flat kettles, mixed usually with quick lime, white of egg, and new milk. A spoonful of slacked lime, the white of one egg, and a pint of new milk, is sufficient for fifteen gallons of sap. A little butter is added to prevent the sap from boiling over. When boiled down sufficiently, it is allowed to *grain*, or form into small crystals, which constitute raw sugar, and then purified in the usual manner.*

4. The raw sugar imported into Europe is still further purified. It is dissolved in water, clarified, boiled down to a proper consistency, and then poured into unglazed conical earthen vessels, where it is allowed to grain. The point of the cone is undermost, and perforated to allow the impurities to separate. The base of the cone is covered with moist clay, the water of which gradually filters through the sugar, and displaces a quantity of impure liquid. The sugar thus purified is called *loaf sugar*. When redissolved and treated in the same way a second time, it is called *refined* sugar. This process appears to have been first practised by the Venetians.

5. In the East Indies, where they make very pure sugar, their process is remarkably simple and economical, but tedious. An account of this process, as practised about Aska and Barampour, has been given by Mr Anderson, surgeon of the Madras establishment. The cane juice is first strained, and then boiled with a little lime to the proper consistency for graining. It is afterwards put into small earthen pots with mouths six inches wide, and allowed to remain at least a month: sometimes six or eight months. A hole is then made in the bottom of the pots, and the liquid syrup suffered to run off from the crystallized sugar. The sugar is put upon a cloth and squeezed, being occasionally moistened with water, the better to remove the remains of the syrup. It is then dissolved in water, and boiled a second time to the proper consistency; milk and some water being added from time to time in order to clarify it, and the scum being removed as it rises. It is poured into small wide-mouthed

* See Dr Rush's Account of the Sugar Maple Tree, Amer. Trans. iii. 64.

pots, suffered to crystallize, and a hole bored in the bottom of the pots to allow the remains of the syrup to run off. To whiten the sugar, the tops of the pots are covered with the leaves of the *creeping vine;* and these are renewed every day for five or six days. When pure *sugar candy* is wanted, the sugar thus obtained is dissolved in water again, and the same process of boiling with milk and scumming is repeated. When poured into pots, thin slices of bamboo are introduced, which prevents it from running into lumps, and induces it to form large crystals.*

6. According to Dr Higgins, who went to the West Indies on purpose to examine the manufacture of sugar, the juice of the sugar cane contains a great number of bodies; but the most important of them (not reckoning sugar and water) are those which he calls *herbaceous matter* and *melasses acid.* Concerning the nature of these substances nothing very precise is known; but the great object of the manufacturer is to remove them, as they impede the crystallizing of the sugar. The *herbaceous matter*† is partly held in solution by the water, partly by the carbonic acid. When the liquid is heated to 140°, the carbonic acid is disengaged, and the herbaceous matter separates in flakes of an olive-green colour. This produces the scum. Lime facilitates the separation, partly by abstracting the carbonic acid, and partly by forming an insoluble compound with the herbaceous matter. Hence its use in the first part of the process. It is called *temper* by the manufacturers. Too much is injurious in the first part of the process. It redissolves the herbaceous matter, or at least deepens the colour of the syrup.‡

The nature of the *melasses acid* is not better known than that of the herbaceous matter; but it combines with the sugar, and forms an uncrystallizable syrup. Lime is necessary in the last part of the process to remove this acid; it combines with it, and the compound runs off with the syrup during the graining of the sugar.§ This acid is no doubt that which exists in unripe canes, and the quantity of it of course diminishes as the cane improves in quality. I have been informed by my friend Dr Clarke, of Dominica, that the quantity of lime necessary is much less when the canes are rich and ripe than when green or lodged, or when they have been cut some time before they are bruised in the mill: and that he has known the juice of rattoon rich canes boiled down into permanent crystals of sugar without the assistance of any lime. He substituted potash instead of lime; but found that the sugar obtained by this method was liable to diliquesce. Soda made the grain firmer, but smaller than usual. These facts would lead to a suspicion that the *melasses acid* is either the *acetic* or the *citric.* Dr Clarke's experiments should exclude the oxalic, tartaric, and malic acids.

* Phil. Mag. xxi. 272.

† This is probably a different substance from any that we know at present. It seems to possess many properties in common with *gluten.* Dr Higgins says that it agrees in its properties with the dregs of refined indigo.

‡ See Higgins' Observations, Phil. Mag. xxiv. 308. § Ibid.

These observations of Dr Clarke agree very well with the account of Dutrone, who made a very great number of experiments on sugar-cane juice, and was very well acquainted with its properties. According to him it chiefly consists of sugar, extractive, and two different kinds of fecula, which are precipitated by lime. He endeavours to prove that unaltered juice contains no acid, and his experiments are sufficient to convince us that the quantity of acid is at least very minute.*

Dutrone's experiments were performed before vegetable chemistry had made nearly the progress which it has now reached. Hence it is difficult, from his description, to recognise the substances which he found in sugar-cane juice. But this loss has been supplied by the experiments of Proust. Living in Spain where the sugar-cane is still cultivated, he had an opportunity of examining its juice. He found it to contain gluten or green fecula, gum, extractive, malic acid, sulphate of lime, and two species of sugar; namely, common sugar, and a species which is incapable of crystallizing, and can only be exhibited in the state of a syrup, and which, for that reason, he calls *liquid sugar*. The quantity of acid was very minute, and probably in a warmer climate than Spain its quantity would be still smaller.†

According to Dutrone, sugar-canes give about half their weight of juice, the specific gravity of which varies from 1·033 to 1·106. It is at first opaque, but when the feculent matter has precipitated, it becomes transparent, and of a green colour. When allowed to stand for some time it runs into acidity, but if the feculent matter be removed it undergoes the vinous fermentation.

7. The mode of extracting sugar from beet-root, is similar to that employed for extracting it from the sugar-cane, only the proportion of sugar is much smaller, not exceeding 2, or, at most, 3 per cent. of the weight of the root.

The beet-roots are collected in the month of October, after having reached their full size. If they be left longer in the earth, the quantity of sugar which they contain is diminished; being replaced, it is said, by *nitre*. Deprived of their leaves, washed and reduced to pulp, their juice is forced out by means of a press. This juice is raised to the temperature of 176°, and about 1 ounce of slacked lime added for every three imperial gallons. The whole is well mixed, and raised to the temperature of 212°. The heat is then withdrawn, and the liquid left to clarify. A portion of the lime falls to the bottom, while another, loaded with impurities, covers the surface of the liquor. The scum is skimmed off from the top, and the clear liquor drawn off by means of a stop-cock, placed at a little distance from the bottom of the vessel. This clear liquid is evaporated as rapidly as possible, till its specific gravity becomes as high as 1·035 or 1·04. Some animal charcoal (about 4 per cent. of the juice) is then added, and the evaporation continued, and when the

* Histoire de la Canne. Premiere Partie, chap. vi. and vii.

† Ann. de Chim. lvii. 148.

liquid has acquired the density of 1·12 or 1·13, it is filtered through a coarse linen cloth. The evaporation is then continued in very shallow pans till it acquires the requisite consistency. It is then let into the cooler, and when its temperature has sunk to about 100°, it is poured into conical unglazed moulds, and allowed to granulate.

8. The raw sugar from the East and West Indies, is usually refined in this country by the process introduced more than 20 years ago by Mr Howard. The raw sugar is dissolved in water, clarified by animal charcoal, and boiled down to the requisite consistency *in vacuo*, at a temperature of about 150°. The vacuum is kept up by means of an air pump, wrought all the time by a steam-engine; and the boilers are globular pans made air tight, and attached to the air pump. By this ingenious contrivance, the whole sugar is obtained without any loss, and freed from all its impurities.

The following table of the specific gravity of solutions of different portions of sugar and water up to the point of saturation, drawn up by M. Niemann, from a set of experiments made on purpose, at the temperature of 63°½, is inserted here, because it may be occasionally useful:—*

Sugar.	Water.	Specific gra.	Sugar.	Water.	Specific gra.	Sugar.	Water.	Specific gra.
0	100	1·0000	24	76	1·1010	48	52	1·2209
1	99	1·0035	25	75	1·1056	49	51	1·2265
2	98	1·0070	26	74	1·1103	50	50	1·2322
3	97	1·0106	27	73	1·1150	51	49	1·2378
4	96	1·0143	28	72	1·1197	52	48	1·2434
5	95	1·0179	29	71	1·1245	53	47	1·2490
6	94	1·0215	30	70	1·1293	54	46	1·2546
7	93	1·0254	31	69	1·1340	55	45	1·2602
8	92	1·0291	32	68	1·1388	56	44	1·2658
9	91	1·0328	33	67	1·1436	57	43	1·2714
10	90	1·0367	34	66	1·1484	58	42	1·2770
11	89	1·0410	35	65	1·1538	59	41	1·2826
12	88	1·0456	36	64	1·1582	60	40	1·2882
13	87	1·0504	37	63	1·1631	61	39	1·2933
14	86	1·0552	38	62	1·1681	62	38	1·2994
15	85	1·0600	39	61	1·1731	63	37	1·3050
16	84	1·0647	40	60	1·1781	64	36	1·3105
17	83	1·0698	41	59	1·1832	65	35	1·3160
18	82	1·0734	42	58	1·1883	66	34	1·3215
19	81	1·0784	43	57	1·1935	67	33	1·3270
20	80	1·0830	44	56	1·1989	68	32	1·3324
21	79	1·0875	45	55	1·2043	69	31	1·3377
22	78	1·0920	46	54	1·2098	70	30	1·3430
23	77	1·0965	47	53	1·2153			

* Annalen der Pharmacie, ii. 340.

9. Sugar procured pure by the preceding methods has a very strong sweet taste, but no smell. Its colour is white; and when crystallized it is nearly transparent. It has often a considerable degree of hardness; but it is always so brittle that it can be reduced without difficulty to a very fine powder. When two pieces of sugar are rubbed against each other in the dark, a strong phosphorescence is visible.

Sugar is not altered by exposure to the atmosphere, excepting only that in damp air it absorbs a little moisture.

10. It is exceedingly soluble in water. At the temperature of 48°, water, according to Mr Wenzel, dissolves its own weight of sugar.* The solvent power of water increases with its temperature; when nearly at the boiling point, it is capable of dissolving any quantity of sugar whatever. Water thus saturated with sugar is known by the name of *syrup*.

Syrup is thick, ropy, and very adhesive; when spread thin upon paper, it soon dries, and forms a kind of varnish, which is easily removed by water. Its specific heat, according to the experiments of Dr Crawford, is 1·086. When syrup is sufficiently concentrated, the sugar which it contains may be obtained in crystals. The syrup is boiled down till it is thick, poured immediately into pans, and kept in a stove or room, heated so as not to be supported by animals for any length of time. The crystals concrete upon small threads placed in the pans for that purpose.† The primitive form of these crystals is a four-sided prism, whose base is a rhomb, the length of which is to its breadth as 10 to 7, and whose height is a mean proportion between the length and breadth of the base. The crystals are usually four or six-sided prisms, terminated by two-sided, and sometimes by three-sided summits.‡ From the experiments of Berzelius, they are composed of

Real sugar	100
Water	5·6
	105·6§

11. The specific gravity of very white sugar, according to the experiments of Fahrenheit, is 1·6065.‖ I found it 1·5629.

12. Sugar, as far as is known, is not acted upon by oxygen gas. The effect of the simple combustibles on it has not been tried; but it does not appear to be great. Azotic gas nor the metals have no sensible action on it.

13. Sugar is altered by the action of the strong acids. Concentrated sulphuric acid poured upon sugar blackens it, and causes it to deposit a charry matter when we dilute the acid with water. If we saturate the sulphuric acid with chalk, and filter, to separate the sulphate of lime formed, we obtain a sweet and bitter-tasted residue,

* Verwandtschaft, p. 308. † Lewis, Neumann's Chemistry, p. 329.
‡ Gillot, Ann. de Chim. xviii. 317. § Annals of Philosophy, v. 264.
‖ Phil. Trans. 1724, vol. xxxiii. p. 114.

which contains hyposulphate of lime in solution. When sugar is long boiled with dilute sulphuric acid, it is converted into *sugar of grapes*, or that species of sugar into which starch is converted by the same process.

By nitric acid it is converted into oxalhydric and oxalic acids. 480 grains of sugar, treated with 6 ounces of nitric acid, diluted with its own weight of water, and cautiously heated, separating the crystals as they formed, yielded 280 grains of oxalic acid. So that 100 parts of sugar yield by this treatment 58 parts of oxalic acid.*

When sugar is dissolved in a concentrated solution of arsenic acid, the liquid becomes gradually red, then purple, and finally brown, while at the same time a portion of the sugar is converted into sugar of grapes.

Muriatic acid acts upon sugar like sulphuric acid. When chlorine or muriatic gas is passed over sugar in powder, it is absorbed, and the sugar is converted into a brown liquid substance, which contains muriatic acid, and which smokes in the air. When chlorine gas is passed through a solution of sugar, it transforms it into oxalhydric acid, while the chlorine is converted into muriatic acid.

If, to a solution of sugar, we add 3 per cent. of oxalic or tartaric acid, the sugar loses the property of crystallizing, and does not recover it, though we saturate the acid with carbonate of lime or of lead.†

But the action of acids on sugar has lately been investigated by MM. Malagutti and Bouchardat.‡ They have ascertained that acids, in general, whether organic or inorganic, even when very dilute, act upon sugar in the same manner when assisted by heat. They first convert it into incrystallizable sugar, then into sugar of grapes, then into incrystallizable sugar, then into ulmic acid; and, finally, if atmospheric air be present, into ulmic and formic acids. After cane-sugar has been changed into sugar of grapes, the conversion of it into ulmic and formic acids, goes on even at the common temperature of the atmosphere. A very minute quantity of acid acts in the same way, but more slowly. The more concentrated the acid is, the more rapid is the action. The presence of atmospherical air is necessary, otherwise sugar cannot be converted into formic acid.

14. Sugar combines with the acidifiable bases. When dissolved in a ley of caustic potash it loses its sweet taste, and leaves, when evaporated, a mass, which is insoluble in alcohol, and which, when the potash is neutralized with sulphuric acid, yields sugar unaltered, and still soluble in alcohol.§

When we introduce sugar in fine powder into a glass filled with ammoniacal gas, and standing inverted over mercury, and allow it to remain as long as it continues to absorb the gas, it diminishes in

* Cruickshanks, Rollo on Diabetes, p. 460.

† Vogel, Ann. de Chim. lxxi. 95. ‡ Jour. de Pharmacie, xxi. 440, and 627.

§ Cruickshanks, Rollo, on Diabetes, p. 460.

bulk, becomes coherent, compact, and soft, so that it can be easily cut with a knife, and gives out an ammoniacal smell. According to Berzelius, to whom we are indebted for this experiment, this compound consists, by weight, of

Sugar	90·28
Ammonia	4·72
Water	5·00
	100·00*

Now, these numbers are proportional to

Ammonia . .	2·125 or 1 atom
Water . .	2·25 or 2 atoms
Sugar . . .	40·64

It will appear afterwards, from the analytical experiments on the composition of sugar, that its atomic weight is 20·25; 40·64, therefore represent 2 atoms of that substance. Consequently this combination of sugar and ammonia must consist of

2 atoms sugar	= 40·5	or per cent. 90·26
1 atom ammonia	= 2·125	— — 4·73
2 atoms water	= 2·25	— — 5·01
	44·875	100·00

When this compound is exposed to the air the ammonia flies off, and the sugar remains unaltered.

When lime is added to a solution of sugar in water, and the mixture boiled for some time, a combination takes place. The liquid still, indeed, retains its sweet taste; but it has acquired also a bitter and astringent one. A little alcohol added to the solution produced a precipitate in white flakes, which appeared to be a compound of sugar and lime. Sulphuric acid precipitated the lime in the state of sulphate, and restored the original taste of the sugar. When the compound of sugar and lime was evaporated to dryness, a semi-transparent tenacious syrup remained, which had a rough bitter taste, with a certain degree of sweetness.†

It would appear from the observations of Mr Daniell, that lime has a tendency to convert sugar into gum. When raw sugar from the West Indies is kept for some time in this country, it is apt to assume a clamminess, with the soft feel of flour. In this state it is called *weak* sugar. Mr Daniell is of opinion that this change is occasioned by the action of the lime (always present in raw sugar) upon the sugar.‡

From the experiments of Mr William Ramsay, it appears that sugar facilitates and increases the solubility of lime and strontian, and forms a combination with them. But barytes seems to act with more energy, and to occasion a partial decomposition of the sugar. For on endeavouring to dissolve it in syrup it was constantly

* Berzelius, Traité de Chimie, v. 239.
† Cruickshanks, Rollo on Diabetes, p. 460.
‡ Quarterly Jour. vi. 32.

converted into a carbonate, and very little in consequence dissolved.*

When a solution of sugar is digested on oxide of lead, the oxide is gradually dissolved, but after a certain interval of time a light white powder makes its appearance. This powder is a compound of sugar and oxide of lead. It is white, light, tasteless, and insoluble in water. According to Berzelius, to whom we are indebted for our knowledge of it,† its constituents are as follows :—

Sugar	41·74 or 10·03	
Oxide of lead	58·26 or 14	= 1 atom
	100·00	

Obviously 1 atom oxide of lead, and $\frac{1}{2}$ an atom of sugar.

Sugar forms with oxide of lead two compounds, one soluble, and the other insoluble. If we digest oxide of lead in a certain quantity of sugar, we obtain a yellowish solution, which reacts as an alkali, and leaves, when evaporated, an incrystallizable mass. It is probable that this soluble compound, which has not been analyzed, is a compound of 2 atoms sugar and 1 atom oxide of lead.

15. M. Desfosses assures us, that solutions of pure sugar in water, whether concentrated or dilute, may be kept any length of time without alteration. But when sugar is dissolved in water which has been boiled over washed yeast, or gluten of wheat, it undergoes a remarkable change. Gas is evolved, consisting of a mixture of carbonic acid and hydrogen gases, and a part of the sugar is converted into a substance having the properties of gum; but which, when digested with nitric acid, does not form mucic acid, but only oxalic acid.‡

16. Sugar possesses the remarkable property of dissolving the carbonate and diacetate of copper, and of forming a green-coloured liquid, from which the oxide of copper is not precipitated by the alkalies, though it is by the prussiate of potash, and by sulphuretted hydrogen. When sugar is boiled with salts of copper, it reduces the copper to the metallic state. When sulphate of copper is employed, metallic copper is precipitated, and a small quantity of a cupreous salt remains in solution. Along with the metal a brown substance falls, which is soluble in ammonia. Nitrate of copper, subjected to the same treatment, gives no precipitate; but the copper is transformed into red oxide, and caustic potash throws down a yellow hydrate of red oxide. When sugar is boiled with acetate of copper, a great deal of red oxide precipitates, acetic acid is disengaged, and the solution, when evaporated, gives an incrystallizable magma.§

Solution of sugar produces no sensible alteration when poured into a solution of nitrate of silver. But when the mixture is boiled,

* Nicholson's Journal, xviii. 9.
† Annals of Philosophy, v. 263. ‡ Jour. de Pharmacie, xv. 602.
§ Vogel, Schweigger's Journal, xiii. 162.

a brownish-black powder falls, which, according to Vogel, is a mixture of metallic silver and oxide of silver.*

When solutions of sugar and corrosive sublimate are mixed, calomel is precipitated. Chloride of gold gives with sugar a precipitate, at first light-red, but gradually becoming dark coloured.† When sugar is mixed with a solution of peroxide of iron, the whole of the peroxide cannot be precipitated by ammonia, as H. Rose first observed.

Malagutti has shown, that potash acts upon sugar precisely as acids do, converting it first into sugar of grapes, then into ulmic acid; and if atmospheric air be present, into ulmic and formic acid.‡

16. Sugar is soluble in alcohol, but not in so large a proportion as in water. According to Wenzel, 4 parts of boiling alcohol dissolve 1 of sugar.§ But this proportion is surely too great. Lewis could only dissolve 1 part of sugar in 12 of boiling rectified spirits, and Margraff in 16 parts. When the solution is set aside for a few days, the sugar separates in elegant crystals.‖ Sugar unites readily with oils, and renders them miscible with water. A moderate quantity of it prevents, or at least retards, the coagulation of milk; but Scheele discovered that a very large quantity of sugar causes milk to coagulate.¶

17. The hydrosulphurets, sulphurets, and phosphurets of alkalies and alkaline earths, seem to have the property of decomposing sugar, and bringing it to a state not very different from that of gum. Mr Cruickshanks introduced a quantity of syrup into a jar standing over mercury, and then added about an equal quantity of phosphuret of lime. Phosphuretted hydrogen gas was immediately extricated. In eight days the syrup was withdrawn: it had lost its sweet taste, and acquired a bitter and astringent one.** From this solution alcohol threw down white flakes, very much resembling those of mucilage separated from water by the same liquid.†† A little sugar was dissolved in alcohol, and phosphuret of lime added to it. No apparent action took place. The mixture, after standing in the open air for some days, was evaporated, and water added. No gas was disengaged, as the phosphuret had been converted into a phosphate. The liquid being filtered and evaporated, a tenacious substance remained, much resembling gum arabic. Its taste was bitter, with a slight degree of sweetness. It did not seem soluble in alcohol. It burned like gum.‡‡

Similar experiments were made by this ingenious chemist with the sulphurets. The sweet taste of the sugar was destroyed; but on account of the solubility of the different products, the nature of the change could not be ascertained.

* Vogel, Schweigger's Journal, xiii. 174. † Ibid. xiii. 174.
‡ Jour. de Pharmacie, xxi. 454. § Verwandtschaft, p. 305.
‖ Lewis, Neumann's Chemistry, p. 329. Margraff, Opusc. i. 217.
¶ Scheele, ii. 32. Dijon Trans.
** This is the taste of phosphuret of lime. †† Rollo on Diabetes, p. 452.
‡‡ Cruickshanks, Rollo on Diabetes, p. 452.

18. When heat is applied to sugar it melts, swells, becomes brownish-black, emits air bubbles, and exhales a peculiar smell, known in French by the name of *caromel*. At a red heat it instantly bursts into flames with a kind of explosion. The colour of the flame is white with blue edges.

When sugar is distilled in a retort, there comes over a fluid which, at first, scarcely differs from pure water; by and by it is mixed with pyromucic acid;* afterwards some empyreumatic oil makes its appearance, and a bulky charcoal remains in the retort. This charcoal very frequently contains lime, because lime is used in refining sugar; but if the sugar, before being submitted to distillation, be dissolved in water, and made to crystallize by evaporation in a temperature scarcely higher than that of the atmosphere, no lime whatever, nor any thing else, except pure charcoal, will be found in the retort. During the distillation, there comes over a considerable quantity of carbonic acid and carburetted hydrogen gas.† Sugar, therefore, is decomposed by the action of heat; and the following compounds are formed from it:—Water, pyromucic acid, oil, charcoal, carbonic acid, carburetted hydrogen gas. The quantity of oil in a separate state is inconsiderable; by far the most abundant product is pyromucic acid. Sugar, indeed, is very readily converted into pyromucic acid; for it makes its appearance always whenever syrup is raised to the boiling temperature.

We are indebted to Mr Cruickshanks for the most precise set of experiments on the decomposition of sugar by heat. 480 grains of pure sugar were introduced into a coated retort, and heated gradually to redness. The products were,

	Grains.
Pyromucic acid, with a drop or two of oil	270
Charcoal	120
Carburetted hydrogen, and carbonic acid gas	90
	480

The pyromucic acid required about 75 grains of a solution of potash to saturate it; and when thus neutralized, no ammonia was disengaged. Hence sugar contains no azote, unless we suppose a very minute portion to be present in the pyromucic acid; which is not the case. The charcoal burns away without leaving any residue. Hence sugar contains no earth nor fixed alkali. The proportion of the gaseous products was 119 ounce measures of carburetted hydrogen, and 41 ounce measures of carbonic acid gas.‡

These experiments are sufficient to show us, that sugar is com-

* Schrickel, in his Dissertation De Salibus Saccharinis, published in 1776, endeavoured to show that pyromucous acid was a mixture of vinegar, oxalic, and tartaric acids. Fourcroy and Vauquelin suggested more lately that it is merely acetic acid united to a little oil. It is now known to be a peculiar acid.

† Scopoli and Morveau, Encyc. Meth. Chim. i. 269.

‡ Rollo on Diabetes, p. 452.

posed entirely of oxygen, carbon, and hydrogen. It is, of course, a vegetable oxide. Lavoisier endeavoured to determine its constituents experimentally; but at that time pneumatic chemistry had made too little progress to permit him to approach very near the truth.

The first chemists who attempted a rigid analysis of sugar, were Gay-Lussac and Thenard. They burnt determinate quantities of crystallized sugar with chlorate of potash, and ascertained the quantity of carbonic acid and water which it yielded, from which they deduced the constituents. Berzelius and Brunner also analyzed sugar. The following table shows the results obtained:—

	Gay-Lussac and Thenard.	Berzelius.	Brunner.
Carbon .	42·47	42·225	42·244
Hydrogen .	6·90	6·600	6·415
Oxygen .	50·63	51·175	51·341
	100·00*	100†	100‡

In 1827, Dr Prout published a very careful and accurate set of experiments on the ultimate composition of simple alimentary substances. Among others, he analyzed all the different varieties of common sugar that occur in commerce.§ The following table exhibits the results which he obtained:—

	Carbon.		Water.	
Pure sugar candy	42·85		+ 57·15	
Impure sugar candy	41·5	to 42·5	+ 58·5	to 57·5
East India sugar candy	41·9		+ 58·1	
English refined sugar	41·5	to 42·5	+ 58·5	to 57·5
East India refined sugar	42·2		+ 57·8	
Maple sugar . .	42·1		+ 57·9	
Beet sugar . .	42·1		+ 57·9	

Of course the first, or pure sugar candy, exhibits the constitution of pure sugar. The oxygen and hydrogen in sugar, Dr Prout considers, with Gay-Lussac and Thenard, as existing in the proportion which constitutes water. Hence the constituents of pure sugar candy are, according to his analysis,

Carbon	42·85
Hydrogen	6·35
Oxygen	50·80
	100·00

M. Liebig, in 1834, repeated these analyses with the most scrupulous attention to accuracy. He obtained, from 100 parts of crystallized sugar,

* Recherches Physico-Chimiques, ii. 288.
† Annals of Philosophy, v. 262, and Traité de Chimie, v. 242.
‡ Annalen der Pharmacie, xiv. 319.
§ Phil. Trans. 1827, p. 355.

Carbon	41·70
Hydrogen	6·45
Oxygen	51·85
	100·00*

Now, if we consider sugar in crystals as a compound of

12 atoms carbon	= 9·00	or per cent.	42·11
11 atoms hydrogen	= 1·375	— —	6·43
11 atoms oxygen	= 11·00	— —	51·46
	21·375		100·00

the proportions of the constituents correspond with the analysis.

Berzelius has shown that crystallized sugar contains an atom of water. Consequently anhydrous sugar must be a compound of

12 atoms carbon	= 9	or per cent.	44·44
10 atoms hydrogen	= 1·25	— —	6·18
10 atoms oxygen	= 10	— —	49·38
	20·25		100·00

Anhydrous sugar of consequence is resolvable into

2 atoms ether . .	C^8 H^{10} O^2
4 atoms carbonic acid .	C^4 O^8
	C^{12} H^{10} O^{10}

The ether, by uniting with 2 atoms of water, is converted into 2 atoms of alcohol. Thus it appears that cane-sugar, during its fermention absorbs water, and is resolved into

Alcohol	51·12
Carbonic acid . . .	48·88
	100·00

An important observation was lately made by MM. Gregory and Demarçay. If, into a very dilute aqueous solution of sugar, we pour permanganate of potash, we obtain a neutral solution of oxalate of potash.

Were we to admit sugar to consist of C^{12} H^{10} O^{10}, then 6 atoms of permanganate of potash composed of Mn^6 O^{42}, would convert 1 atom of sugar into 6 atoms of oxalic acid, composed of C^{12} O^{18} + 6 (K O). The H^{10} O^{10} of the sugar, of course, become water, while the Mn^6 O^{24} are equivalent to 6 atoms of manganesious acid.†

We are indebted to M. Edmund Fremy for an important set of experiments on the distillation of sugar, mixed with anhydrous lime.‡

The best proportions are, 1 part of sugar and 8 parts of lime. The lime must be in fine powder, and the sugar must be intimately

* Annalen der Pharmacie, ix. 21. † Ann. de Chim. et de Phys. lxiii. 139.
‡ Annalen der Pharmacie, xv. 277.

mixed with it, so that the minutest particle of it may be surrounded with lime. The capacity of the vessel in which the process is conducted, ought to be twice that of the powder contained in it, because the mixture swells up considerably during the distillation. The heat must be applied slowly. After a certain time water is disengaged from the sugar, which, by its combination with the lime, occasions the evolution of so much heat that the fire may be withdrawn. The reaction continues for some time strong, and then suddenly terminates of itself. Scarcely any gas is evolved. But an oily matter passes over, having an ethereal smell, and a light-amber colour.

When this oily-looking matter is agitated with water, one portion of it dissolves, while another portion remains unacted upon. When the watery solution is heated to between 158° and 176°, a volatile liquid passes over, having a burning taste and an agreeable smell. It is completely soluble in water, and boils at 140°. It was repeatedly analyzed, and found composed of

Carbon	61·82 or 3 atoms	= 2·25	or per cent.		62·07
Hydrogen	10·67 or 3 atoms	= 0·375	—	—	10·34
Oxygen	27·51 or 1 atom	= 1	—	—	27·59
	100·00	3·625			100·00

It is evident, from this analysis, and from the properties above described, that this liquid is *acetone*.

The oil, which is insoluble in water, is purified by rectifications, though it is peculiarly difficult to free it from all traces of acetone.

It is colourless, has an agreeable smell, is soluble in alcohol and ether, but insoluble in water. It boils at 183°. It was analyzed by M. Fremy, who obtained

Carbon	72·34 or 6 atoms	= 4·5	or per cent.		73·47
Hydrogen	10·17 or 5 atoms	= 0·625	—		10·20
Oxygen	17·49 or 1 atom	= 1	—	—	16·33
	100·00	6·125			100·00

If we double the atoms of the acetone, it will be evident that this oily matter differs from it by the absence of an atom of water. For

Acetone . . .	$C^6\ H^6\ O^2$
The oil	$C^6\ H^5\ O$
Difference . . .	$H\ O$

Fremy, on this account, has given it the name of *metacetone*.

2 atoms of sugar . . $C^{24}\ H^{22}\ O^{22}$

may be resolved into

3 atoms of metacetone .	$C^{18}\ H^{15}\ O^3$
6 atoms carbonic acid .	$C^6\ \ O^{12}$
7 atoms water . .	$H^7\ O^7$
	$C^{24}\ H^{22}\ O^{22}$

Thus we see that 2 atoms of sugar may be resolved into 3 atoms metacetone, 6 atoms carbonic acid, and 7 atoms water. And 1 atom of sugar may be resolved into 3 atoms of acetone, 3 atoms of carbonic acid, and 2 atoms water. For 1 atom sugar is C^{12} H^{11} O^{11}.

3 atoms acetone is .	C^9	H^9	O^3
3 atoms carbonic acid .	C^3		O^6
2 atoms water . .		H^2	O^2
	C^{12}	H^{11}	O^{11}

When starch and gum are substituted for sugar, and distilled with lime, the same products are obtained. The starch seems to furnish more metacetone than acetone, while the gum gives more acetone than metacetone.

SECTION II.—OF LIQUID SUGAR.

Liquid sugar was first pointed out by Proust. He has shown that it exists in a variety of fruits and vegetable juices. It is distinguished from every other species of sugar, by being incapable of crystallizing. It can only be exhibited in a liquid state. It is transparent and colourless when pure, and is more soluble in alcohol than common sugar. By means of that liquid it may be separated from common sugar, when they happen to be mixed. It exists in the sugar-cane juice, and constitutes, according to Proust, a considerable portion of the molasses. It exists also in grapes, peaches, apples, and other fruits.* From the experiments of Auarie it appears, that a liquid sugar may also be obtained from the stalks of the *Zea Mays*, or Indian corn; but no method tried was capable of inducing it to crystallize.† From the experiments of Vogel and Bouillon Lagrange, there is reason to suspect that liquid sugar may be merely common sugar deprived of the power of crystallizing, by being combined with an acid.

SECTION III.—OF SUGAR OF GRAPES AND STARCH.

That grapes contain abundance of sugar has been long known. The Duc de Bullion first extracted it from the juice of grapes, and Proust pointed out the difference between it and common sugar. The juice of grapes, according to him, yielded from 30 to 40 per cent. of this sugar.‡ The sugar of grapes is not so white as common sugar, but it crystallizes much more readily.§

Proust has published a long dissertation on the properties of this sugar, and the method of extracting it from grapes. It was of great importance on the continent during the last war, on account of the difficulty of obtaining sugar from the West Indies.

Verjuice, or the liquid obtained from unripe grapes, contains tartar, sulphate of potash, sulphate of lime, much citric acid, a little malic acid, extractive, and water; but neither gum nor sugar. As

* Proust, Ann. de Chim. lvii. 131.
† Ann. de Chim. lx. 61.
‡ Jour. de Phys. xxix. 5, and lvi. 113.
§ Nicholson's Jour. xiv. 178.

the grapes advance to maturity, the citric acid gradually disappears, and gum and sugar appear in its place.

The juice of ripe grapes contains also gluten and fibrous matter, merely in a state of mixture, and therefore separable by the filter, or still better by boiling and skimming the liquid. The substances held in solution are chiefly sugar, syrup, gluten, gum, and extractive. When this juice is evaporated to dryness, it yields from a third to a fifth of solid matter, according to the species of grape employed, and the season of the year.

To extract the sugar from this juice, Proust saturated the acids which it contains with potash, boiled it down to a half, and left it at rest. By this means several of the salts subsided. Its specific gravity was 1·215. It was then mixed with blood, heated, skimmed, filtered, and boiled down to a syrup. It gradually becomes crystallized, and resembles the raw sugar from the West Indies. In this state its specific gravity is about 1·500. This raw sugar, according to Proust, is composed of

Crystallizable sugar . .	75·00
Syrup, or uncrystallizable sugar	24·44
Gum	0·31
Malate of lime . . .	0·25
	100·00

Besides some extractive, the quantity of which cannot well be ascertained. The syrup holds in solution a considerable quantity, probably more than half its weight, of crystallizable sugar; but it is difficult to separate it.

The raw sugar thus obtained is not so sweet as that from the sugar cane, since four parts of the latter will go as far as five parts of the former. But it may be applied to all the purposes of common raw sugar.

This raw sugar may be refined precisely in the same way as that of the sugar-cane. It is then white, but inferior in consistence to common sugar. It is not so sweet, and has a striking resemblance to the sugar of honey. It does not crystallize, but assumes the form of sphericles. It is not so soluble as the sugar of canes, and is therefore more easily separated from the other substances in the juice of grapes.

Proust informs us that the raw sugar from grapes, when diluted sufficiently with water, ferments and is converted into wine.

Starch may be converted into a sugar possessing exactly the properties of sugar of grapes, by mixing it with about 4 times its weight of water, and about $\frac{1}{100}$th part of its weight of sulphuric acid, boiling the mixture for thirty-six hours, supplying water as fast as it evaporates; then saturating the acid with lime, separating the sulphate of lime, and concentrating the liquid by sufficient evaporation.

This curious fact was accidentally discovered by Kirchoff, a Russian chemist, as he was employed in a set of experiments to

convert starch into gum. He conceived that the starch could be rendered soluble in water by boiling it with very dilute sulphuric acid; and by prolonging the boiling, he gradually observed the conversion of the starch into sugar. Vogel ascertained that during the conversion of starch to sugar, no gas whatever is extricated. Mr Moore* and M. de Saussure† ascertained, that the quantity of sulphuric acid was not diminished by the process. Saussure ascertained that 100 parts of starch, when converted into sugar, become 110·14 parts. Hence he drew as a conclusion, that starch sugar is merely a compound of starch and water in the solid state.‡ According to his analysis, the constituents of starch sugar are as follows:—

Oxygen	55·87
Carbon	37·29
Hydrogen	6·84
	100·00

Dr Prout has subjected the sugar of starch to an analysis, by means of oxide of copper, and found it composed of

Carbon	36·20 or 12 atoms	= 9	or per cent.	36·36
Hydrogen	7·09 or 14 atoms	= 1·75	— —	7·07
Oxygen	56·71 or 14 atoms	= 14	— —	56·57
	100·00§	24·75		100·00

Or, supposing it anhydrous,

12 atoms carbon	= 9	or per cent.	40
12 atoms hydrogen	= 1·5	— —	6·66̇
12 atoms oxygen	= 12	— —	53·33̇
	22·5		100

It differs from common sugar, by containing two additional atoms of water. Hence it is resolvable into alcohol and carbonic acid, without absorbing any water from the liquid in which the fermentation takes place.

Braconnot has shown that by a similar process, saw-dust, straw, linen rags, and even the bark of trees, may be converted into a sugar similar to that of grapes or starch.‖

Starch sugar has the remarkable property of combining with common salt, and forming a compound which crystallizes in pyramidal dodecahedrons and rhomboids, which contain 6 or 7 per cent. of water of crystallization. These crystals dissolve readily in water and absolute alcohol. According to Brunner, they are composed (supposing them anhydrous) of

Sugar	75 or 22·5
Common salt . . .	25 or 7·5
	100

* Phil. Mag, xl. 134. † Annals of Philosophy, vi. 424. ‡ Ibid. vi 426.
§ Phil. Trans. 1827, p. 373. ‖ Ann. de Chim. et de Phys. xii. 181.

We see from this, that it consists of an atom of each constituent.

Honey, which bees collect from flowers, is a concentrated solution of grape sugar. It is well known that honey, as it is deposited in the cells of the combs by the bees, is a semifluid transparent liquid, having a yellow colour, and a peculiar sweet taste. When this honey is left at rest it gradually separates into two portions. The one remains in a liquid state, the other becomes solid, and assumes the form of small whitish-coloured sphericles. The liquid portion, so far as is known, exactly resembles the liquid sugar from the sugar-cane; while the granulated portion is identical with the sugar of grapes. The liquid sugar is easily separated from the crystallized portion, by washing the crystals in alcohol, which dissolves the liquid sugar much more easily than the solid. The crystals are needles diverging from a centre, and constituting little spheres. The constituents of these crystals of sugar of honey, according to the analysis of Prout, are

Carbon	36·36
Hydrogen	7·07
Oxygen	56·57
	100·00*

obviously consisting of the same number of atoms as starch sugar.

SECTION IV.—OF MUSHROOM SUGAR.

M. Braconnot obtained from the juice of the *agaricus volvaceus*, by evaporation, a species of sugar, which differs from common sugar. It crystallizes in four-sided prisms with square bases. It has such a disposition to crystallize, that when a very weak aqueous solution of it is put upon the surface of a vessel, it is immediately sprinkled with small acicular crystals. When heated this sugar melts, swells, and takes fire, giving out the odour of caromel. There remains a small quantity of charcoal, which is destitute of alkali. Acids do not deprive this substance of the power of crystallizing as they do common sugar. When digested with nitric acid it produces abundance of oxalic acid; but no bitter principle. It is capable of undergoing the vinous fermentation.†

This sugar is colourless. It is much less sweet than common sugar, and is not so soluble either in water or alcohol.

Besides *agaricus volvaceus*, it has been found in *agaricus acris*, *theogalus*, *campestris*; in *boletus juglandis*; *peziza nigra*; *merulius cantharellus*; *phallus impudicus*; *hydnum hybridum*, and *repandum*.

A quantity of this sugar, extracted by M. Blanchet from the *cantharellus esculentus*, and the *clavellaria coralloides*, was analyzed by Liebig and Pelouze. It did not ferment with yeast, and was composed of

* Phil. Trans. 1827, p. 373. † Ann. de Chim. lxxix. 278.

Carbon	39·06
Hydrogen	7·71
Oxygen	53·23
	100·00*

Now it will be seen, in the next Section, that this is the composition of mannite. Mushroom sugar, then, is nothing else than mannite.

SECTION V.—OF MANNA.

Manna was long considered as a substance which fell from the heavens, till incontestable experiments demonstrated it to be an exudation from trees. It has the form of oblong globules or masses, of a yellowish-white colour, and some degree of transparency. It is the produce of various trees, but is chiefly procured from the *fraxinus ornus*, a species of ash, which grows abundantly in Sicily and Calabria. It partly exudes spontaneously during the summer months, and is partly obtained by incisions. The juice gradually concretes into a solid mass, or it is dried in the sun or in stoves.† The *fraxinus rotundifolia* also yields manna, as well as the *ornus*. It exudes likewise from the *pinus larix*. This exudation is known by the name of manna of Briançon. It is so much mixed with turpentine, that it is very little used. Vogel has shown also that it exists in the leaves of the *apium graveolens*, or *celery*.‡ And Fourcroy and Vauquelin extracted a substance resembling manna, in considerable quantity, from onions.§

The manna of the shops is obtained from the *ornus*. But there is a tree in New South Wales, the *eucalyptus mannifera*, which, according to Dr Mudie, yields a manna exactly similar to that of the *ornus*. It is now imported from Botany Bay for medical purposes.‖ To obtain pure manna it is only necessary to dissolve the manna of the shops in boiling alcohol, and allow the solution to cool. The manna crystallizes.

The crystals are white, and have the form of four-sided needles. Its taste is sweet and agreeable, and when placed upon the tongue, it dissolves rapidly, producing a sensation of cold. It is very soluble in water, and forms a syrup which crystallizes readily, when sufficiently concentrated. It dissolves very readily and abundantly in alcohol, and crystallizes on cooling. When digested in nitric acid it yields both oxalic and saclactic acids, whereas sugar only yields oxalic acid.¶ It does not ferment like sugar, and of course

* Ann. de Chim. et de Phys. lxiii. 140.

† See Neumann's Chemistry, p. 325, from which all the accounts of manna to be found in chemical books have been copied.

‡ Schweigger's Jahrbuch, vii. 365. § Ann. de Chim. lxv. 161.

‖ Jour. de Pharmacie, xviii. 705. We learn from Mr Wellsted, that the Bedouin Arabs collect yearly above 700 lbs. of manna in the neighbourhood of Mount Sinai. The manna of that country is supposed to be an exudation from the *Hedysarum Alhagi*; that of the wilderness is said by Ehrenberg to come from a species of *Tamarix*. Whether it be similar to the manna of Moses, cannot be ascertained. See Ann. der Pharmacie, xxv. 80.

¶ Proust, Ann. de Chim. lvii. 144.

does not seem capable of furnishing alcohol.* In a set of experiments on the juice of the common onion (*allium cœpe*), Fourcroy and Vauquelin found that, at a temperature between 66° and 80°, it gradually underwent the acetous fermentation, without emitting any gas; and that by this process a quantity of uncrystallizable sugar, which it contained, assumed most of the properties of manna. It was not precisely the same, however, with manna, for it did not yield saclactic acid when treated with nitric acid.

The common manna of the shops, according to the experiments of Fourcroy and Vauquelin, consists of four different ingredients. 1. Pure manna, which constitutes at least $\frac{3}{4}$ths of the whole. 2. A little common sugar, which makes it fermentable to a small extent. 3. A yellow matter with a nauseous odour, to which the purgative quality of manna seems owing. 4. A little mucilage converted into saclactic acid. This last ingredient seems hypothetical. Several substances, by fermenting, seem to be converted into manna. The sugar in onion juice has been already mentioned. Fourcroy and Vauquelin found likewise that fermented melon juice contained manna, though none could be detected in it before the fermentation. Manna appears sometimes to be formed and deposited by insects.†

Manna has been analyzed both by M. de Saussure, Dr Prout, M. Oppermann, Henry and Plisson, and Brunner. The following table exhibits the results of these analyses:—

	Saussure.‡	Prout.§	Oppermann.‖	Henry and Plisson.¶	Brunner.**
Carbon .	38·53	38·7	39·98	38·77	40·084
Hydrogen .	7·87	6·8	7·80	8·48	7·529
Oxygen .	53·60	54·5	52·22	52·85	52·387
	100·00	100·0	100·00	100·10	100

If we calculate from Dr Prout's analysis, we find that mannite is a compound of

9½ atoms carbon	= 7·125	or per cent.	38·77
10 atoms hydrogen	= 1·25	— —	6·80
10 atoms oxygen	= 10·00	— —	54·43
	18·375		100·00

But Liebig and Pelouze consider mannite as composed of

12 atoms carbon	= 9·0	or per cent.	39·56
14 atoms hydrogen	= 1·750	— —	7·69
12 atoms oxygen	= 12·0	— —	52·75
	22·750		100·00

Numbers which approach very nearly to the results obtained by Oppermann.

* Du Puytren and Thenard, Ann. de Chim. lix. 51.

† See Klaproth, Gehlen's Jour. iv. 328.

‡ Annals of Phil. vi. 424.

§ Phil. Trans. 1827, p. 384.

‖ Poggendorf's Annalen, xxiii. 445.

¶ Jour. de Pharmacie, xx. 63.

** Ann. der Pharm. xiv. 320.

M. Mitouart found a sugar in the root of the pomegranate tree, which he called *grenadin*. Boutron-Charlard and Guillemet have shown it to be identical with mannite.*

About the year 1815, specimens of a sweet substance were brought from Botany Bay. They were snow-white, in the form of tears, and had obviously dropped in a liquid state from some vegetable. I was informed that these tears were collected in a plain covered with wood; but of what species I could not learn. Some bushels of it might have been collected. These tears had a sweet and agreeable taste. They dissolved in much greater quantity in alcohol than common sugar, and when the alcohol cooled it deposited the sugar abundantly in needle-form crystals. The form of these crystals approached that of manna; but was not quite the same. Nor did it make so cooling an impression on the tongue. It was therefore a peculiar species of sugar; though approaching much nearer to manna than any of the preceding species. It is very much to be wished that more complete information could be obtained respecting this species of sugar, and that sufficient quantities of it could be sent over to this country, to permit an accurate set of experiments on it to be made.

SECTION VI.—OF LIQUORICE SUGAR.

Liquorice sugar is the inspissated juice of the *glycyrrhiza glabra*, a plant which is a native of Spain, and other countries situated in the south of Europe. It is cultivated in England, chiefly, it is said, in the neighbourhood of Pontefract; and Pomet commends the English liquorice root as the best of any.

The use of this root in medicine, and the method of obtaining its inspissated juice in a solid form when it is denominated liquorice, or black sugar, seems to have been known to the ancients. For Pliny gives a description of the *glycyrrhiza*, which applies very well to our plant, and mentions the method of obtaining the inspissated juice, and its use in medicine.†

What is called *black sugar*, or *liquorice sugar*, in this country, is merely the inspissated decoction of the roots of the *glycyrrhiza*. It is manufactured in Spain, and it is said also in Germany and Holland. It comes to this country wrapt up in bay leaves. The German and Dutch liquorice is said to be adulterated with the *rob* of plumbs.

Pure liquorice sugar is best obtained from the decoction of the root, or from *black sugar*. Dissolve the *black sugar* in water, clarify the solution with the white of egg, without which it cannot be filtered. Filter and then pour sulphuric acid into the solution, which occasions a precipitate of the sugar, united to a certain quantity of vegetable albumen. Collect this precipitate on a filter, and wash it till the water ceases to become coloured. Then dissolve it in alcohol, which, leaving the albumen, dissolves only the sugar combined

* Ann. der Pharm. xiv. 321. † Plinii Hist. Nat. lib. xxii. cap. 9.

with the acid. Let fall into the solution, drop by drop, a solution of carbonate of potash, till the liquid ceases to be sensibly acid. Filter and evaporate. The sugar remains under the form of a yellow, translucid mass, cracked in all directions, and easily detached from the vessel in which it was evaporated.

Its taste is similar to that of liquorice root. It is soluble both in water and alcohol. When heated it swells up like borax, takes fire, and burns with a lively flame and much smoke. When thrown in the state of a powder into the flame of a candle, it burns like lycopodium, but with a whiter colour. It has a great affinity for acids, salifiable bases, and salts.

With acids it forms compounds little soluble in water, and almost insoluble in water acidulated with an acid. Some time elapses before these compounds precipitate from a dilute solution. The vegetable acids form these combinations, as well as the mineral acids.

Sulphated liquorice sugar is deposited at first like a light cloud, and gradually collects into a coherent mass, which becomes slowly viscid, like a half-fused resin, when kneaded in warm water. Its taste, after being well washed, is sweet, like that of liquorice sugar; but the compound collects on the tongue, and dissolves very slowly in the saliva. Boiling water dissolves it, and when the saturated solution is allowed to cool, it assumes the form of a tremulous jelly. The colour of the solution is light-yellow. It is soluble in alcohol, and the compound is not thrown down when the solution is poured into water. When the alcoholic solution is evaporated, there remains a translucent, light-yellow substance, which, when dry, is transparent and straw-yellow. It burns like liquorice sugar, and leaves no trace of ashes.

The *acetate of liquorice sugar* is obtained in the same way as the sulphate, which it resembles in its properties, excepting that it is much more soluble in boiling water, and forms a firmer jelly. When dry it has the form of white crusts, having a sweet taste.

Liquorice sugar combines also with bases. Hence it happens, that when we precipitate it by an acid, and then saturate the acid with a base, the sugar combines with the excess of that base. Hence in such cases we must beware of adding any excess of base. It is better to leave a very little of the acid unsaturated with the base.

If we mix the carbonates of potash, barytes, or lime, with liquorice sugar, and digest the mixture, the carbonic acid is disengaged by little and little, and the sugar combines with the base. When the combination (which is soluble) does not contain an excess of alkali, its taste is purely sweet. When treated with an acid, not the smallest trace of carbonic acid is given out. These combinations dissolve readily in water; but are not so soluble in alcohol. They do not crystallize, and when dry resemble extracts. They are not decomposed by carbonic acid. When we add carbonate of barytes or of lime to an alcoholic solution of sulphated liquorice sugar, and digest the mixture a long time, we obtain a portion of the compound in a state of solution; but in proportion as the digestion is prolonged, a

larger proportion precipitates, which is soluble in water. This is the compound of the sugar with the base, free from carbonic acid.

Liquorice sugar combines also with *salts;* though the pure sugar, recently extracted from the roots of the plant, does not combine so readily as common black sugar does. When we separate this last by means of carbonate of potash, from its sulphate dissolved in alcohol, we obtain a brown precipitate, completely soluble in water, which gives when evaporated a black mass, cracked in every direction, but not crystallized, and having a sweet taste.

Liquorice sugar precipitates the greater number of metallic solutions. For example, solutions of nitrate of copper, acetate of lead, sulphated peroxide of iron, protochloride of tin. But corrosive sublimate is not precipitated. These precipitates are combinations of the sugar with the salt, and when decomposed by sulphuretted hydrogen, they give no (or very little) matter soluble in cold water. But some, as for example, the precipitate with protochloride of tin, are decomposed by alcohol. Alcohol dissolves from this precipitate a mixture of sugar and muriate of sugar, and leaves a residue containing protoxide of tin.

If we drop a solution of sugar into trisacetate of lead, we obtain a precipitate composed of sugar and oxide of lead. Sulphuretted hydrogen decomposes this precipitate. But the sugar retains sulphuret of lead, and cannot be purified by filtration.*

Berzelius informs us, that liquorice sugar may be extracted from the leaves of the *abrus precatorius.*† This is the tree which yields the red peas, black at one extremity, used for necklaces. The sugar extracted from the *polypodium vulgare*, has considerable resemblance to liquorice sugar. But Berzelius has shown that its chemical characters are quite different.‡

The root of *glycyrrhiza glabra* was subjected to analysis, by M. Robiquet, who obtained the following substances from it:—

(1.) Starch, first observed in it by M. Lautour.

(2.) Gluten, which is separated by boiling.

(3.) Liquorice sugar.

(4.) Phosphates and malates of lime, and magnesia.

(5.) A brown thick resinous oil, which gives an acrid character to the decoction of liquorice.

(6.) A substance similar in its properties to asparagin; but crystallizing in octahedrons.

(7.) Woody fibre.§

It appears from the experiments of M. Zier, that the root of this plant contains copper; and that this metal is to be found also in the decoction.‖

SECTION VII.—OF SUGAR OF FIGS.

The sugar of figs may be seen in a concrete state upon the out-

* Berzelius, Ann. de Chim. et de Phys. xxxvii. 186.

† Traité de Chimie, v. 260. ‡ Ibid. p. 262.

§ Ann. de Chim. lxx. 185. ‖ Jour. de Pharmacie, xix. 226.

side of that fruit in the state in which it is usually sold in the shops in this country. If we dissolve it in boiling alcohol and set the liquid aside, we may easily obtain it in the state of crystals. These crystals have a form different from that of common sugar; nor do they appear to my taste quite so sweet. Hence they must constitute a distinct species.

SECTION VIII.—OF SARCOCOLLIN.

Sarcocolla usually comes to this country from Persia, Turkey, and India. It is commonly in the state of oblong globules, from the size of a pea to a grain of sand. Its colour is yellow and it has the translucency and much of the appearance of gum arabic. It exudes from all the parts (especially the calyces) of the *penæa mucronata*, a shrub which is a native of Persia and Arabia. This substance consists principally of a peculiar principle, to which Pelletier has given the name of *sarcocollin*.*

To obtain it we have only to digest sarcocolla in ether, to dissolve a resinous matter which is present. Absolute alcohol will now take up the sarcocollin, which it lets fall when evaporated.

The colour, as I have obtained it, is brownish-white. Its taste is sweetish, leaving at the same time an impression of bitterness, and in the mouth it dissolves like gum. It cannot be made to crystallize.

It is soluble in water, and the solubility is augmented by heat. It is soluble also in alcohol; but insoluble in ether.

When digested in nitric acid it is converted into oxalic acid. The tincture of nut-galls, when poured into a solution of sarcocollin, occasions a copious light-yellow precipitate. The infusion of nut-galls only throws down a slight precipitate, and gallic acid nothing at all. It is precipitated also by diacetate of lead; but not by nitrate or acetate of lead, corrosive sublimate, nitrate of silver, sulphate of zinc, or sulphate of copper. Concentrated sulphuric acid dissolves it, but deepens its colour.

The constituents of sarcocollin, as determined by Pelletier, are

Carbon	57·15 or 22 atoms	= 16·5	or per cent.	57·14
Hydrogen	8·34 or 19 atoms	= 2·375	— —	8·22
Oxygen	34·51 or 10 atoms	= 10	— —	34·64
	100·00†	28·875		100·00

SECTION IX.—OF GLYCERIN.

This substance was discovered by Scheele, and called by him *sweet principle of oils.* He showed that it is evolved when an oil is boiled with oxide of lead and a little water.‡ The watery portion holds the glycerin in solution. If we decant off this water and

* I had detected its peculiar nature and characters thirty years before; but chemists had not attended to the facts which I stated. See the different editions of my System of Chemistry.

† Ann. de Chim. et de Phys. li. 198. ‡ Scheele, Opusc. ii. 189.

throw down the oxide of lead which it contains by sulphuretted hydrogen, and then evaporate, we obtain the glycerin in a state of purity. Chevreul afterwards showed that it is separated whenever an oil is converted into soap.* And from subsequent experiments of various chemists, there seems reason to conclude, that when an oil is saponified it is decomposed into two substances; namely, glycerin and margaric acid, oleic acid, or some one of the other soap-making acids.

To obtain glycerin we have only to digest an oil with an alkaline ley till we convert it into soap. The soap being separated, the alkaline liquid remaining is saturated with sulphuric acid, and any excess of acid is removed by carbonate of barytes. Filter and evaporate to the consistence of a syrup. Dissolve the syrup in alcohol, and filter in order to separate the alkaline sulphate. When the alcoholic solution is evaporated, the glycerin is obtained in a state of purity.

Thus obtained, it is a colourless syrup, uncrystallizable, but capable of being converted into a white solid substance. Its taste is sweet, but it is destitute of smell. When concentrated till its specific gravity is 1·252, it still retains water. Chevreul kept it for two months in the vacuum of an air pump along with sulphuric acid. Its specific gravity became 1·27, but it still retained water. According to Pelouze, its specific gravity, when anhydrous, is 1·280.† It attracts moisture from the atmosphere and dissolves readily in alcohol. When heated in a retort the greatest part of the glycerin may be distilled over unaltered; but when the retort begins to get red hot, a liquid passes over containing acetic acid and a black empyreumatic oil, while a charry matter remains in the retort. In the open air glycerin burns with a blue flame. Though almost solid it possesses a solvent power, scarcely inferior to that of water itself. It dissolves the vegetable acids, the deliquescent salts, and many other salts that are not deliquescent, as sulphates of potash, soda and copper, nitrates of silver and potash, the alkaline chlorides, and potash and soda in great quantity. Nitric acid converts it into oxalic acid; but very slowly. Dissolved in 4 times its weight of water it undergoes no alteration, and does not ferment even when mixed with yeast. With potash it forms a compound soluble in alcohol. It is not precipitated by subacetate of lead, and is itself capable of dissolving oxide of lead.

Chevreul found the constituents of glycerin, specific gravity 1·27, to be

Carbon	40·071 or 3 atoms	= 2·25	or per cent.	39·13
Hydrogen	8·925 or 4 atoms	= 0·5	— —	8·69
Oxygen	51·004 or 3 atoms	= 3·0	— —	52·18
	100·000‡	5·75		100

* Sur les Corps Gras, p. 209. † Ann. de Chim. et de Phys. lxiii. 19.
‡ Sur les Corps Gras, p. 340.

Liebig's analysis led him to consider glycerin as composed of

6 atoms carbon	= 4·5	or per cent.	43·37
7 atoms hydrogen	= 0·875	— —	8·43
5 atoms oxygen	= 5	— —	48·20
	10·375		100·00

There can be little doubt that these numbers constitute a near approximation to the constitution and atomic weight of glycerin.

If we adopt the view presented by Liebig and Pelouze, from their analysis of stearin, which they find composed of $C^{146}\ H^{143}\ O^{17}$, and which they consider as composed of

2 atoms stearic acid .	$C^{140}\ H^{134}\ O^{10}$
1 atom glycerin . .	$C^{6}\ H^{7}\ O^{5}$
2 atoms water . .	$H^{2}\ O^{2}$
	$C^{146}\ H^{143}\ O^{17}$

we must consider 1 atom of glycerin as combined in stearin with 2 atoms of stearic acid, in which case 10·375 will be its true atomic weight, and Liebig's atomic numbers the true number of atoms which enter into its constitution.

The plants containing sugar are very numerous. Margraff first pointed out a method of separating it from them. The plant suspected to contain it is reduced to powder or pulp, and boiled with strong alcohol. The liquid is filtered while hot, and set aside in a close vessel. In a few days the sugar separates from the alcohol and crystallizes.*

The following are the chief plants from which it has been actually extracted by chemists :†

The flower of the rhododendron ponticum
The sap of the acer saccharinum
——————— betula alba
——————— asclepias syriaca
——————— heraclium sphondilium
——————— cocos nucifera
——————— juglans alba
——————— agave Americana‡
——————— fucus saccharinus
——————— ficus carica
——————— ceratonia siliqua§
The juice of arundo saccharifera
——————— arundo bambos‖
——————— zea mays
The roots of pastinaca sativa¶

* Margraff, Opusc. i. 216. † See Gren's Handbuch, ii. 123.
‡ Margraff, Opusc. i. 213. § Klaproth, Gehlen's Jour. iv. 326.
‖ Tennant's Indian Recreation, ii. 288. ¶ Margraff, Opusc. i. 213.

The roots of sium sisarum*
——— beta vulgaris and cicla*
——— daucus carota*
——— apium petroselinum
The bulb of the allium cœpe.

It is proper to observe, however, that from the *daucus carota*, Margraff could obtain only an uncrystallizable syrup. The sugar from the sap of the *agave Americana* bore a greater resemblance to manna than to sugar.† It is very seldom that sugar exudes spontaneously from vegetables; sometimes, however, it does. Tears of a sweet substance were observed upon the *ceratonia siliqua*, or *locust tree*, some time ago in Naples. These tears were examined by Klaproth, and found to be sugar mixed with a little tannin and oxalate of potash.‡ The inspissated juice of the bamboo (*arundo bambos*) is known in India by the name of *sacar nambu;* a term which is supposed to be the origin of our word *sugar*, and constitutes a species of sugar celebrated as a medicine. How far it agrees with common sugar has not been ascertained.

Small crystals of sugar are found occasionally in the flower of the *rhododendron ponticum*. I have received some of these crystals from my friend Dr Charles Mackenzie, but too small in quantity to admit of a rigid examination. They have no regular shade; but in other respects seem to agree with common sugar in their properties. The same sugar has been noticed by Fourcroy, Vauquelin, and Bosc.§

The list of the saccharine plants would be greatly extended were we to add all sweet-tasted fruits, such as grapes, &c., which obviously contain sugar, and some of the mushroom tribe, from which Humboldt affirms he extracted it.‖

Sugar has now become an essential part of the food of Europeans. It contains perhaps a greater proportion of nourishment than any other vegetable substance in the same bulk. It has the advantage of most other articles of food, in not being liable to be injured by time nor by the weather. If we believe Dr Rush, the plentiful use of it is one of the best preventatives of the diseases occasioned by worms. It has been long supposed to have a tendency to injure the teeth; but this prejudice is now given up. It has the property of preserving other vegetable substances from putrefaction; and accordingly is often employed for that purpose, constituting the base of conserves, &c.

* Margraff, Opusc. i. 213. † Margraff, i. 241. ‡ Gehlen's Jour. iv. 327.
§ Ann. de Chim. lxiii. 102.
‖ The reader will find a much fuller list than I have given, in John's Tabellen, p. 11. I have not ventured to make use of his materials, because I have no means of determining the particular species of sugar which each vegetable contains.

CHAPTER V.

OF AMYLACEOUS SUBSTANCES.

If a quantity of wheat flour be formed into a paste, and then held under a very small stream of water, kneading continually till the water runs off from it colourless, the flour by this process is divided into two distinct constituents. A tough substance of a dirty-white colour, called *gluten*, remains in the hand; the water is at first milky, but soon deposits a white powder, which is known by the name of *starch*. A sweet-tasted mucilaginous substance remains dissolved in the water.

The starch obtained by this process is not altogether free from gluten; hence its colour is not very white, and it has not that fine crystallized appearance which distinguishes the starch of commerce.* Manufacturers employ a more economical and more efficacious process. Good wheat is allowed to steep in cold water till it becomes soft, and yields a milky juice when squeezed. It is then taken out of the water; put into coarse linen sacks, which are subjected to pressure in a vat filled with water; a milky juice containing abundance of starch exudes, and mixes with the water of the vat. This process is repeated as long as the wheat yields any milky juice. The sack and its contents are then removed. The starch soon falls to the bottom of the vat; and the water which covers it gradually ferments, in consequence of the substance which it holds in solution. Alcohol and vinegar, or lactic acid, are formed in it, partly, no doubt, at the expense of the starch. The acid, thus evolved, dissolves all the impurities, and leaves nothing behind but starch. It is then poured off, and the starch edulcorated with water. It is afterwards dried by a moderate heat. During the drying it usually splits into small columnar masses, which have a considerable degree of regularity. The water which has stood over the starch was analyzed by Vauquelin. It contains a considerable portion of alcohol and of acetic acid. The acid holds in solution gluten somewhat altered, phosphate of lime, and ammonia.†

Starch was well known to the ancients. Pliny informs us, that the method of obtaining it was first invented by the inhabitants of the island of Chio.‡

There is a considerable number of substances, which have so great a resemblance to starch, that they have been classed along

* Its colour may be much improved by digesting it in an alkaline ley of moderate strength.

† Ann. de Chim. xxxviii. 248. See La Fabrique de l'Amidon, by Du Hamel de Monceau. See also Gmelin's Handbuch der Technischen Chemie, ii. 737. The reader will find a description of the process followed by our manufacturers in making starch, in Phil. Mag. xxix 166.

‡ Lib. xviii. cap. 7.

with it by chemists. It will be proper to take a view of all these substances here. This Chapter therefore will be divided into nine Sections.

SECTION I.—OF COMMON STARCH.

Common starch is extracted from wheat by the process described in the beginning of this Chapter. But the purest starch of all is procured from the potatoe, simply by rasping it down over a seirce, and passing a current of water over the raspings. The water passes through the seirce milky from the starch suspended in it. The starch is allowed to fall to the bottom, and is two or three times washed with pure water. It is then allowed to dry. 100 parts of good potatoes, when treated in this way, furnish, according to the experiments of Einhoff, about 15 parts of starch.

Besides wheat and potatoes, starch exists in a great number of other vegetables, all the seeds of grassy plants used for food, as oats, rice, rye, barley, &c., contain it. It exists in most bulbous roots. Thus, besides the potatoe, the *convolvulus batatas* and *edulis*, the *helianthus tuberosus*, the *Iatropha manihot*, &c., may be mentioned. *Arrow-root** consists entirely of very pure starch. It is extracted from the roots of the *maranta arundinacea* (*Monandria Monogynia*), a plant which is a native of South America and of Jamaica, and, as Dr Joxburgh informs us, from those of the *curcuma angustifolia* (also *Monandria Monogynia*), which is a native of Malabar. The *maranta* is about two feet high, has broad-pointed and somewhat hairy leaves, and bears small white flowers in clusters, and globular fruit of the size of currants. The roots are dug when a year old, well washed and beaten in deep wooden mortars, till they are reduced to a milky pulp. This is well washed in clear water, and the fibrous parts of the root being carefully separated, nothing remains but the starch, which is passed through a coarse cloth, and the liquid allowed to settle. The water is drawn off and the starch washed repeatedly with water till quite clean. The starch is then dried in the sun. Arrow-root is very pure starch, and the *maranta* yields a greater quantity of this principle than most other vegetable bodies. In commerce it is said that potatoe starch is frequently substituted for arrow-root.

The substance imported into this country from South America, and known by the names of *Cassava* and *Tapioca*, is also a very pure starch. It is obtained from the roots of the *jatropha manihot* (*Monœcia Monadelphia*), a native of South America. These roots are peeled and subjected to pressure in a kind of bag made of rushes. The juice that is forced out is a deadly poison (containing strychnina), and is employed by the Indians to poison their arrows. But it deposits gradually a white starch which, when properly washed, is innocent. What remains in the bag consists chiefly of the same

* So called because it is considered as an antidote to the poisoned arrows of the Indians.

starch. After being thoroughly washed, it is dried in smoke, and afterwards granulated by being forced through the meshes of a kind of sieve.

Sago is another variety of pure starch which is extracted from the pith of a species of palm called *Sagus raphia*, which grows in the Moluccas, Philippines, and other East India islands. The palm is cut into pieces of five or six feet in length: the woody part is cut off one side, exposing the pith lying, as it were, in the hollow of a canoe. Cold water is poured in, and the pith well stirred; by which means the starch is separated from the fibrous part, and passes through with the water when the whole is thrown on a seirce. The sago, thus separated, is allowed to settle; the water is poured off; and when it is half dry it is granulated, by being forced through a kind of funnel. It is said to acquire its grey colour while dried in an artificial heat. This substance is employed as an article of food, and its nourishing properties are well known.*

Salop is another variety of starch, which comes to this country from Persia; but is said also to be manufactured in Europe. It is supposed to be the prepared roots of different species of *orchis*, as the *morio*, *mascula*, *bifolia*, *pyramydalis*. According to Moult, the bulbous roots of these plants are deprived of their cuticle, baked in an oven for 10 or 12 minutes, which gives them the semitransparency, and then fully dried in a moderate heat.† Like sago, salop is used only as a nourishing article of food. It is said by Dr Percival to have the property of concealing the taste of salt water.‡

The very nutricious article of food distinguished in Scotland by the name of *sowans*, and in England called *flummery*, is made from the husk of oats, by a process not unlike that by which common starch is made. The husk of the oat (called *seeds*) is separated from oatmeal by the sieve. It still retains a considerable portion of farinaceous matter. It is mixed with water, and allowed to remain for some days till the water has become sour. The whole is then thrown upon a seive. The milky water passes through; but all the husk remains behind. The water thus obtained is loaded with starchy matter, which soon subsides to the bottom. The sour liquor is decanted off, and about an equal quantity of fresh water added. This mixture when boiled forms a very nourishing article of food; and the portion of the sour water which still adheres to the starch gives the whole a pleasant acidity.

It is curious enough that the starch-maker's water, notwithstanding the great quantity of acid which it contains, likewise the still sourer water of sowans, are swallowed greedily by hogs. They fatten upon it.

Starch, when pure, has a fine white colour, no smell, and very little taste. When kept dry it continues long unaltered though exposed to the air. When squeezed between the fingers it gives a peculiar sound. Its specific gravity, as stated by Raspail, is 1·53.

* Forest's Voyage, p. 39. † Phil. Trans. lix. 2. ‡ Phil. Mag. xviii. 161.

When examined under the microscope, it appears under the form of rounded grains, which vary in their shape, not only when the starch is extracted from different plants, but even from the same plant. They are lodged in particular cells in the plant, which produces them and increase in size as the plant advances to maturity. According to Raspail, they consist of vesicles inclosing within them a clear transparent colourless liquid. In cold water these vesicles remain entire and insoluble; but when put into boiling water they burst, the central liquid dissolves in the water, and the husk or outer coat of the vesicle becomes much more bulky and transparent than it was before, and floats undissolved in the liquid. Heat causes these vesicles to burst, and to empty themselves of the liquid which they contain.* Thus it appears that starch consists essentially of two distinct substances. 1. The liquid portion which fills each little vesicle. This liquid portion consists of water, holding in solution a peculiar substance, which M. Guerin-Varry, to whom we are indebted for an examination of its properties, has distinguished by the name of *amidin*.† 2. The vesicular portion of the grain, which is insoluble in water, may be distinguished by the name of *amylin*.‡ We must consider the properties of each of these substances separately.

According to the experiments of M. Guerin-Varry, potatoe starch is composed of

Exterior tegumentary amylin .	2·12
Amidin	38·13
Amylin	59·75
	100·00§

1. *Amidin.* *Amidin*, or the soluble part of starch, may be obtained in the following manner:—Put 1 part of potatoe starch into 100 parts of water, and boil the mixture for a quarter of an hour, and then pour the whole into a precipitating glass. By degrees the integuments of the vesicle of the starch precipitate to the bottom of the vessel. Decant off the clear liquid, filter it, and boil it gently down to the consistence of a syrup. Pour this syrup upon a cloth and squeeze it through. The triticin is retained by the cloth; but a liquid passes through, which must be evaporated by the vapour-bath, at a temperature below 212°. Some amylin is deposited. We must filter again to get rid of it, and evaporate anew. These alternate filtrations and evaporations must be repeated as long as any amylin continues to appear. The liquid is now evaporated to dryness. It leaves a substance completely soluble in cold water. This new solution is deprived of its colour by animal charcoal, purified and

* Chimie Organique, p. 6. † Ann. de Chim. et de Phys. lvi. 231.

‡ M. Guerin-Varry has called it *amidine*, but this name is too near *amidin*, when pronounced in the English way to enable us to distinguish the one substance from the other. I have therefore been obliged to employ a new term and I have adopted *amylin*, from the Greek word αμυλον, *starch*, as sufficiently appropriate.

§ Jour. de Pharmacie, xxii. 210.

precipitated by alcohol, thrown upon a filter, and washed by alcohol at the temperature of 186°. It is finally dissolved in as little water as possible, and evaporated to dryness over the vapour-bath.

Amidin thus obtained is a very light substance, yellow when anhydrous, but white when it contains water. It has neither taste nor smell. When in thin plates it is transparent; and is easily reduced to powder.

M. Biot examined its action on polarized light, and found that it caused a deviation of the rays to the right, about three times as great as common sugar—a deviation which is sensibly the same with that of his *dextrine*.

When heated it melts and swells up, but is not volatilized. Cold water dissolves it, and acquires the consistence of mucilage. It is still more soluble in boiling water. In alcohol and ether, it is quite insoluble.

It adheres very firmly to the glass or procelain vessel, in which its aqueous solution is evaporated. Its aqueous solution acquires an acid taste in a few days, and becomes very slightly muddy.

When digested in nitric acid, it forms first oxalhydric acid, and finally oxalic acid.

100 parts of amidin, and 250 parts of sulphuric acid at the temperature of 150°, furnish, according to the experiments of M. Guerin-Varry, 95·8 parts of anhydrous sugar.

According to the experiments of the same chemist, amidin is composed of

Water	3·0
Ashes	0·2
Pure amidin	96·8
	100·0

He analyzed pure anhydrous amidin, and obtained

Carbon	39·72 or 10	atoms =	7·5
Hydrogen	7·13 or $10\frac{3}{4}$	atoms =	1·34
Oxygen	53·15 or 10	atoms =	10·0
	100·00		18·84

M. Guerin has examined also the amidin from the starch of potatoes, and states its composition to be C^{14} H^{10} O^{8}.* He dried it *in vacuo* at 265°, and found its constituents

Carbon	53·23 or 14 atoms	=	10·5	or per cent.	53·16
Hydrogen	6·27 or 10 atoms	=	1·25	— —	6·33
Oxygen	40·50 or 8 atoms	=	8	— —	40·51
	100·00		19·75		100†

But from the experiments of Prout, I think it more probable that the constituents are

* Jour. de Pharmacie, xxii 210.

† Ann. de Chim. et de Phys. lxi. 86.

10 atoms carbon	= 7·5	or per cent.		40·00
10 atoms hydrogen	= 1·25	—	—	6·67
10 atoms oxygen	= 10·0	—	—	53·33
	18·75			100·00

If 18·75 be the atomic weight of amidin, then the hydrous amidin analyzed by M. Guerin-Varry contained about half an atom of water, or was composed of

2 atoms amidin	37·5	or per cent.		97·08
1 atom water	1·125	—	—	2·92
	38·625			100

2. *Amylin.* Amylin, or the portion of starch which constitutes the outer covering of the spericles, and which is insoluble in water, possesses the following characters, as they have been investigated by M. Guerin-Varry :—

When dried at the temperature of 212°, it is slightly yellow. The pellicles of which it is composed are easily reduced to powder. It gives a fine blue with solution of iodine. When the liquid is heated to 194°, this colour vanishes, but it appears again when the liquid cools.

Though kept for 100 hours, in 10,000 times its weight of boiling water, it does not dissolve, nor is it resolved into globules, as Raspail, and Biot, and Persoz affirm it to be.

It is insoluble in water, both cold and hot, in alcohol, and in ether. But it swells in water, becomes white, and shows a certain degree of elasticity.

When 100 parts of amylin are digested with 800 parts of nitric acid, 25·46 parts of anhydrous oxalic acid are formed.

When digested for 12 hours, with $2\frac{1}{2}$ times its weight of sulphuric acid, at the temperature of 151°, we obtain a syrup, which, being boiled for 12 hours, with 200 times its weight of water, is converted into starch sugar. Some vegeto-sulphuric acid is formed at the same time. 100 parts of amylin treated in this way gave 88·92 parts of anhydrous, or 110·57 parts of hydrous sugar.

Amylin, according to the analysis of M. Guerin-Varry, is composed of

Water	10·99
Ashes	1·00
Real amylin	88·01
	100·00

Being analyzed by means of oxide of copper, it yielded

Carbon	52·74 or 17 atoms	= 12·75	or per cent.		52·31
Hydrogen	6·59 or 13 atoms	= 1·625	—	—	6·66
Oxygen	40·67 or 10 atoms	= 10·00	—	—	41·03
	100·00	24·375			100·00*

* M. Guerin-Varry has analyzed the amylin from potatoe starch, and says that it is composed of C^{20} H^{10} O^{12}. See Jour. de Pharm. xxii. 210.

He afterwards dried amylin *in vacuo*, in the temperature of 275°, and obtained from it*

Carbon	52·80 or	10 atoms =	7·5	or per cent.	53·10
Hydrogen	4·35 or	5 atoms =	0·625	— —	4·42
Oxygen	42·85 or	6 atoms =	6·0	— —	40·48
	100·00		14·125		100·00

But I am persuaded that these numbers do not constitute very near approximations to the truth. Dr Prout analyzed pure wheat starch and arrow root, with every possible attention to accuracy. He found the constitution as follows:—

	Wheat Starch.	Arrow Root.
Carbon .	37·5	36·400
Hydrogen .	6·94	7·066
Oxygen .	55·56	56·534
	100·00	100·000

These substances were exposed for 20 hours to a temperature of between 200° and 212°: the wheat lost 12·5, and the arrow-root 15 per cent. of their weight. Being now analyzed, the constitution of both was identical, being composed of

Carbon	42·800
Hydrogen	6·355
Oxygen	50·845
	100·000

The wheat starch being exposed for 6 hours more, to a heat between 300° and 350°, lost 2·3 per cent. more of its weight, and was composed of

Carbon	44
Hydrogen	6·22
Oxygen	49·78
	100·00

The starch had now acquired a slightly yellow colour, and seemed to have suffered some change in its properties. Hence 14·8 per cent. seems to be about the utmost quantity of water that dry wheat starch can part with, without decomposition.

The arrow-root subjected for 6 hours longer to a heat between 300° and 350°, lost 1·38 per cent. more of its weight, or in all 16·38 per cent.; but it had now assumed a deep yellow colour, and was altered in its properties.†

Now in these experiments, the amidin and amylin were confounded together. Yet as the hydrogen and oxygen occur always in the proportions which constitute water, it is obvious that the

* Ann. de Chim. et de Phys. lxi. 84. † Phil. Trans. 1827, p. 376.

number of atoms of hydrogen and oxygen, must either be equal both in amidin and amylin; or that whatever preponderancy of either shall occur in amidin, the opposite preponderancy must occur in amylin. But in M. Guerin-Varry's analysis, there is a preponderancy of hydrogen, both in amidin and amylin. Dr Prout's analysis of wheat flour, dried in a temperature between 300° and 350°, leads to the conclusion that its constituents were

12 atoms carbon	= 9	or per cent.	44·44
10 atoms hydrogen	= 1·25	— —	6·17
10 atoms oxygen	= 10	— —	49·39
	20·25		100·00

Now if amidin be composed of 10 atoms carbon, 10 atoms hydrogen, and 10 atoms oxygen, it is probable that the above numbers very nearly represent the atomic constitution of amylin.

The late experiments of Payen, made with very great care, approach pretty nearly to those of Prout. He obtained from pure amylin, dried at 130°,

Carbon	43·31
Hydrogen	6·49
Oxygen	50·20
	100·00*

Numbers which lead obviously to the conclusion, that amylin is a compound of 12 atoms carbon, 10 atoms hydrogen, and 10 atoms oxygen.

It is probable that the *dextrine* of Biot and Persoz consists chiefly of amidin. But M. Guerin-Varry has shown that the dextrine of these gentlemen, is not a single vegetable principle, but a mixture of several. They have stated as an essential chemical property of dextrine, that it ferments when mixed with yeast. M. Guerin-Varry prepared a quantity of dextrine by their process, and found, as they had stated, that it fermented with yeast. He digested it in alcohol, and extracted a sweet-tasted substance, which fermented abundantly with yeast. But the residue which was insoluble in alcohol, did not undergo the least fermentation when mixed with yeast. Iodine gave it a blue colour, though Biot and Persoz state that iodine gives dextrine the red colour of wine. When the portion of dextrine insoluble in alcohol is put into water, one portion of it dissolves while another portion remains undissolved. It would appear from this, to be a mixture of sugar, amidin, and amylin, and probably of other substances.†

Payen obtained a quantity of pure dextrine, by a very laborious process.‡ When pure it dried readily into scales or plates, which did not adhere to porcelain or glass dishes. Being analyzed by M. Payen, he obtained

* Ann. de Chim. et de Phys. lxi. 371. † Ibid. lvi. 239.
‡ Ibid. lxi. 372.

Carbon	42·24
Hydrogen	6·20
Oxygen	51·56
	100·00

These numbers approach so nearly the constituents of amylin, as to leave no doubt of the identity of the two substances.

SECTION II.—OF HORDEIN.

This substance was first noticed and described by Proust in 1817.* It may be obtained from barley-meal by the following process:—Make the barley-meal into a paste with water, and wash it by a current of water dropping on it. The starch and *hordein* are washed away. If we boil this mixture in acidulous water, the starch is taken up, and the hordein remains unaltered. It amounts, according to Proust, to from 54 to 56 per cent. of the barley meal employed.

It is a yellow powder, granular to the touch, and has very much the appearance of sawings of wood. It is insoluble in water and alcohol, does not yield ammonia when distilled, and when treated with nitric acid, it furnishes oxalic acid, acetic acid, and traces of a bitter substance. According to Proust, during the malting of barley, the hordein is converted into starch.

Hordein has been subjected to analysis by M. Marcet. He found its constituents

Carbon	44·2
Hydrogen	6·4
Azote	1·8
Oxygen	47·6
	100·0†

As hordein yields no ammonia when distilled, the probability is, that the 1·8 per cent. of azote found by Marcet, proceeded from an admixture of common air. If we leave out the azote, the other constituents approach

12 atoms carbon
11 atoms hydrogen
10 atoms oxygen.

But, as in the other substances analogous to starch, the oxygen and hydrogen exist in the proportions requisite to form water, it is probable that this is the case also in hordein, and that the true constituents are

12 atoms carbon	= 9	or per cent.	44·44
10 atoms hydrogen	= 1·25	— —	6·17
10 atoms oxygen	= 10	— —	49·39
	20·25		100

* Ann. de Chim. et de Phys. v. 339.

† Mem. de la Societé Physique et d'Histoire Naturelle de Geneve, iii. 317.

Now this is the very constitution of amylin deduced from the analyses of Prout and Payen.

We are indebted to M. Marcet also, for an analysis of the starch of malt, the substance into which hordein is converted, according to Proust, during the process of malting. He found the constituents as follows :—

Carbon	41·6
Hydrogen	6·6
Oxygen	51·8
	100·0

These numbers correspond with

11 atoms carbon	= 8·25	or per cent.	42·30
10 atoms hydrogen	= 1·25	— —	6·41
10 atoms oxygen	= 10	— —	51·29
	19·5		100·00

If any confidence can be placed in this analysis, the hordein, during the process of malting, loses one atom of carbon. Hence doubtless, in part, the cause of the evolution of carbonic acid gas, which takes place during the process of malting.

SECTION III.—OF LICHENIN.

This name has been given by M. Guerin-Varry to what was formerly called the starch of the *cetraria islandica*, or *Island moss*,* well known as the food of the rein-deer.

Good *cetraria islandica* contains about 44½ per cent. of lichenin. It may be extracted in the following way :—Minch the lichens very fine, and for every pound of lichen take 18 pounds of water, in which about an ounce of common pearl ash has been dissolved. Let the lichen macerate for 24 hours in the water, taking care to stir it about frequently during this interval. The alkali dissolves a bitter matter, almost insoluble in water, and the liquid acquires a brown colour. Throw the whole upon a cloth, and let the liquid drain off from the lichen. Macerate it again in an additional quantity of water, and repeat the maceration till all the bitter principle and potash are removed. We must not expose the lichen to pressure, because a good deal of the lichenin would be forced out along with the water. Boil the lichen thus purified (supposing 1 lb. employed) in 9 pounds of water, till they are reduced to 6 pounds. Filter the liquid while hot through a cloth, and subject the residue to pressure. The liquid thus obtained is, while hot, limpid and colourless. On cooling, it becomes covered with a pellicle, and at last the whole is converted into a grey-coloured opaque jelly, which contracts by degrees, cracks in all directions, and separates from the water in which it was dissolved. When laid upon blotting paper, this liquid separates by little and little, and the jelly remains. When quite dry it has a

* Herberger has given it the name of *cetrarin*. It was first examined by Berzelius, who obtained it, but not absolutely pure.

black colour, is hard, and breaks with a vitreous fracture. The black colour is owing to the presence of an extractive matter, rendered insoluble in water by the preceding treatment. If, therefore, we dissolve the matter in boiling water, we obtain, when the liquid cools, a colourless, but opaque jelly, which, when dry, is pure lichenin.

Lichenin thus obtained has little taste, but a slight smell of lichen, which adheres to every thing extracted from lichens.

When dry it is yellowish; but while it retains water its colour is white. When in thin plates it is transparent. Tough.

When put into cold water it swells up into a kind of jelly, but does not dissolve. In boiling water it dissolves into a mucilage, constituting a jelly when much concentrated. It is coloured blue by iodine, but much less intensely than amylin. The aqueous solution of lichenin is precipitated in white flocks when mixed with alcohol or ether. Water redissolves the alcoholic, but not the ether deposit. The aqueous solution of lichenin exposed to the air becomes acid in a few days.

Diacetate of lead dropt into an aqueous solution of lichenin, forms a copious precipitate, insoluble in water, but soluble in acetic acid. According to Herberger, lichenin possesses alkaline properties combining with acids, but its salts are incapable of crystallizing.*

When 100 parts of lichenin are digested with 250 parts of sulphuric acid at 151°, and then treated in the usual way, we obtain 93·91 parts of anhydrous starch sugar.

100 parts of lichenin digested at 70°, with 600 parts of nitric acid of the specific gravity 1·34, for 28 days, and then heated to 104°, gave a great deal of oxalhydric acid. Being afterwards heated to 140°, and then allowed to cool, it gave 48·17 parts of oxalic acid.†

The constituents of hydrated lichenin, according to the analysis of M. Guerin-Varry, are

Water	7
Ashes	0·8
Lichenin	92·2
	100·0

He subjected anhydrous lichenin to an analysis, by means of oxide of copper, and obtained

Carbon	39·33 or 10 atoms =	7·5	or per cent.	39·74
Hydrogen	7·24 or 11 atoms =	1·375	— —	7·28
Oxygen	53·43 or 10 atoms =	10·0	— —	52·98
	100·00‡	18·875		100

But the circumstance rendering the accuracy of this analysis of lichenin doubtful is, that it exhibits 11 atoms of hydrogen to 10 of oxygen; while we have seen that the previous experiments of Thenard and Gay-Lussac, and of Dr Prout, render it exceedingly probable, that in all the varieties of starch these two constituents

* Jour. de Pharmacie, xvii. 229.

† Guerin-Varry, Ann. de Chim. et de Phys. lvi. 247. ‡ Ibid, p. 248.

exist in the proportions requisite for forming water. Probably the true constitution of lichenin is

10 atoms carbon	= 7·5	or per cent.	40·00
10 atoms hydrogen	= 1·25	— —	6·67
10 atoms oxygen	= 10·0	— —	53·33
	18·75		100·00

These numbers do not deviate far from the result of Guerin-Varry's analysis. If they are correct, they show that lichenin is in its constitution isomeric with amidin, although the two substances differ somewhat from each other in their properties. Herberger has observed that it is poisonous.*

SECTION IV.—OF INULIN.†

This substance was first noticed and described, in 1804, by M. Valentine Rose, the friend and fellow-labourer of Klaproth.‡ He found it in the roots of the *inula helenium*. John obtained it from the *anthemis Pyrethrum*;§ Pelletier and Caventou, from the bulbous roots of the *colchicum autumnale*;‖ Payen from the tubers of the *Dahlia pinnata* and *purpurea*;¶ Braconnot from the *helianthus tuberosus*, and the roots of the *Datisca cannobina*;** and Trommsdorf from the *Menyanthes trifoliata*.††

When the roots of the *inula helenium* are boiled in water, the decoction, after standing some hours, deposits the inulin in the form of a white powder like starch. The *dahlia purpurea* yields it in greatest abundance; but it is with equal ease extracted from the roots of the *inula helenium* and *helianthus tuberosus*. The roots are rasped down and boiled with water. The boiling-hot solution is passed through a cloth, and, if muddy, is clarified by the white of an egg. It is then evaporated till a pellicle begins to appear on the surface, and allowed to cool. The inulin is deposited in the form of a white powder. Let it be collected on a filter, washed, and dried.

The roots of *inula helenium* contain 11$\frac{1}{9}$th per cent. of helenium; those of *leontodon taraxicum* 12 per cent.; and those of *cichorium intybus* 12$\frac{1}{4}$th per cent.

Inulin is a fine white powder, destitute of taste and smell. Its specific gravity is 1·356.‡‡ When heated a little above 212° it gives out water, and enters into fusion. On cooling, it assumes the form of a grey, scaly mass, easily reducible to powder. In this state it

* Jour. de Pharmacie, xvii. 228.

† *Inulin* has been distinguished by various names. John called it *Helenin*; Trommsdorf, *Alantin* and *Menyanthin*; Henry, *Elecampin*; Payen, *Dahlin* and *datiscin*; obviously from the names of the plants in which it has been detected.

‡ Gehlen's Jour. iii. 217. § Chem. Schriften, iv. 126.

‖ Ann. de Chim. et de Phys. xiv. 69.

¶ Jour. de Pharmacie, ix. 383. The *dahlia purpurea*, on the Continent, is called *Georgina purpurea*.

** Ann. de Chim. et de Phys. iii. 278; and xxv. 357.

†† Jour. de Pharmacie, xviii.

‡‡ Berzelius, Traité de Chemie, v. 209.

has a sweet and gummy taste, and alcohol extracts from it a brown matter, leaving a gum very soluble in water. When strongly heated it behaves like starch, and yields no empyreumatic oil. Iodine gives it a yellow colour, and renders it insoluble in water.

100 parts of cold water dissolves only 2 parts of inulin; but it is very soluble in boiling water, and forms with it a mucilage, which, however, has not the consistence of mucilage of starch. When we evaporate the solution the inulin collects at the surface of the liquid, under the form of a mucilaginous skin; and when the liquid cools, it is deposited in the form of a powder. When the aqueous solution of inulin is long boiled, it loses the property of depositing the inulin on cooling, and becomes gummy.

When inulin is dried by the assistance of heat it forms, like sago, hard, yellowish, translucent grains.

It is insoluble in cold alcohol, and this liquid throws it down from its solution in water. Boiling alcohol dissolves a very small quanity, which it deposits unaltered on cooling.

The dilute acids dissolve it easily, and transform it, with the assistance of boiling, into sugar. This change takes place more easily with inulin than with starch. Nitric acid converts it into oxalhydric and oxalic acid, without any trace of mucic acid.

With the alkaline bases it behaves as amylin does. Caustic potash dissolves it; and, when the alkali is saturated with an acid, the inulin precipitates. Barytes water renders the solution of inulin muddy; but the precipitate is soluble in boiling water. Strontian and lime water occasion no precipitate.

The aqueous solution of inulin is precipitated by infusion of nut-galls. But when the liquid is raised to the boiling temperature the precipitate is redissolved.

When inulin and common starch are mixed in a solution, the starch precipitates along with the inulin when the latter predominates; but when there is an excess of starch, the inulin remains in solution.*

Such are the properties of inulin, determined chiefly by M. V. Rose. No attempt has yet been made to determine its constituents. Raspail informs us that he has examined it under the microscope, and found it composed of grains of a smaller size, but organized like those of common starch.†

SECTION V.—OF LIGNIN.

This is the name given by chemists to the fibrous portion of wood, freed by digestion in water, alcohol, ether, muriatic acid, alkaline ley, and chlorine, from every thing that these reagents are capable of taking up. Fourcroy seems to have been one of the first of modern chemists who admitted it as a vegetable principle, and treated of it formally in his system.‡ Some curious experiments

* Pelletier and Caventou. † Chimie Organique, p. 73.

‡ See Nicholson's Translation of Fourcroy's System of Chemical Knowledge, vol. viii. p. 114, published in 1804.

on its conversion into sugar by sulphuric acid, and into ulmin by potash, were published in 1819 by Braconnot.* In 1827 it was subjected to a chemical analysis by Dr Prout.† Indeed, it had been analyzed long before by Gay-Lussac and Thenard.‡ And, in 1812, Count Rumford published some curious experiments on the specific gravity, carbonization, &c., of different kinds of wood.§

Lignin, properly so called, constitutes the skeleton of the trunks and branches of trees. It varies in its texture, colour, hardness, and specific gravity, according to the species of tree from which it is procured; and probably it varies also somewhat in its chemical composition. Its texture is fibrous, or perhaps, more correctly speaking, it consists of longitudinal vessels, containing in the fresh tree certain nutritive juices. Wood, in general, contains about 96 parts of lignin, and 4 parts of other matter removed by the action of the reagents above specified. No doubt the difference of colour is owing to the presence of some colouring matter different from lignin, though we do not possess the means of separating it.

Lignin, when perfectly dry, is a non-conductor of electricity; but it is a conductor when allowed to absorb moisture from the atmosphere, which it does with avidity, though it swims upon the surface of water. This is owing to the numerous pores which it contains, and which are filled with air. For, *in vacuo*, wood sinks to the bottom of water. From the experiments of Count Rumford,‖ it appears that the specific gravity of the following woods, when the pores are filled with water instead of air, are:—

Poplar	1·4854
Lime	1·4846
Birch	1·4848
Fir	1·4621
Plane	1·4599
Beech	1·5284
Elm	1·5186
Oak	1·5344

When heated in close vessels it becomes black without melting, being converted into charcoal, which still exhibits the texture of the wood from which it was derived. It gives out carbonic acid, and carbonic oxide gases, water, acetic acid, pyroxylic spirit, and many other substances which have not hitherto been particularly examined.

When different species of wood are burnt in the open air, the heat evolved, during the combustion of 1 lb. of each, is capable of heating the following number of pounds of water, from 32° to 212°, according to Count Rumford:—¶

* Ann. de Chim. et de Phys. xii. 172. † Phil. Trans. 1827, p. 380.
‡ Recherches Physico-Chimiques, ii. 284.
§ Schweigger's Jour. viii. 160 and 165. ‖ Ibid. viii. 169.
¶ Schweigger's Jour. viii. 190.

	Dried in the open air.	Dried in the oven.
Oak .	29·7	——
Elm .	30·3	34·5
Apple .	31·8	31·6
Cherry .	33·3	36·9
Ash .	33·7	35·4
Beech .	33·7	36·3
Plane .	——	36·1
Service .	——	36·1
Fir .	34·0	37·4
Poplar .	34·6	37·2
Lime .	34·8	40·6
Birch .	34·8	33·2

When lignin is exposed to the action of chlorine it becomes snow-white, but does not dissolve. Concentrated sulphuric acid changes it in the cold to gum. If we dilute the matter thus obtained with water, and boil the gum, it is converted into sugar. Concentrated nitric acid renders lignin yellow, and gradually reduces it to powder, and at last dissolves it, and converts it into oxalic acid. Lignin, when boiled with concentrated muriatic acid is altered. The acid acquires a red colour, which gradually changes to brown, while the wood blackens, but does not dissolve. When dried it burns with flame, showing that it has not been converted into charcoal.

When lignin is heated with an equal weight of strong caustic potash ley, a liquid is obtained, which contains oxalic and acetic acids, and acids throw down a substance from it bearing a close analogy to lignin.

The first attempt to analyze lignin was by Gay-Lussac and Thenard. They obtained

	Lignin of Oak.	Lignin of Beech.
Carbon .	52·53	51·45
Hydrogen .	5·69	5·82
Oxygen .	41·78	42·73
	100·00	100·00

Dr Prout analyzed the lignin of box and willow, dried in the atmosphere, and found the constituents

	Box.	Willow.
Carbon .	42·70	42·6
Hydrogen .	6·37	6·38
Oxygen .	50·93	51·02
	100·00	100·00

A given weight of each of these was now exposed for 24 hours to a temperature of 212°, and afterwards for six hours longer, by means of an oil-bath, to a temperature between 300° and 350°. At the end of this time, they were found to have lost, per cent.,

Box.	Willow.
14·6	14·4

Analyzed, in this state of desiccation, they were found composed of

	Box.	Willow.
Carbon .	50	49·8
Hydrogen .	5·55	5·58
Oxygen .	44·45	44·62
	100·00	100*

These numbers lead to the following atomic constitution of lignin:—

15 atoms carbon	= 11·25	or per cent. 50·00
10 atoms hydrogen	= 1·25	— — 5·55
10 atoms oxygen	= 10·00	— — 44·45
	22·5	100

Thus it appears that lignin contains more carbon than any of the other substances belonging to the genus starch.

The inner fibrous bark of flax *(linum usitatissimum)* and hemp *(cannabis sativa)*, constituting the well known substances, lint and hemp, and also the fibres of cotton, are very analogous to lignin in their chemical characters, though hitherto they have not been subjected to a chemical analysis.†

* Phil. Trans. 1827, p. 380.

† M. Braconnot, by digesting saw-dust of wood, or potatoe starch, in concentrated nitric acid, obtained a mucilaginous solution, quite transparent. Water coagulated it, and separated a white caseous substance, to which he has given the name of *xyloidin*. It possesses the following properties:—

1. A white insipid powder, not reddening litmus paper.
2. When mixed with tincture of iodine, that tincture loses its colour, and we obtain a yellow compound.
3. Bromine has no action on it.
4. It softens and coheres together in boiling water, but does not dissolve.
5. Nor is it soluble in sulphuric acid diluted with twice its weight of water. But with concentrated sulphuric acid it forms a colourless solution, not precipitated by water, and containing a gummy matter.
6. Soluble in concentrated muriatic acid, but again precipitated by water unaltered in its properties.
7. Dissolves in dilute nitric acid, but is precipitated by alkalies and by water. If the acid solution be evaporated, oxalic acid is obtained.
8. Acetic acid dissolves it abundantly when assisted by heat, and forms a thick mucilage, which, when mixed with water, coagulates into a hard, white matter. The acid solution forms a fine brilliant varnish, and renders cloth impermeable to water.
9. Ammonia has no action on it. Nor yet potash ley, unless it be long boiled with it, when a brown solution is obtained, from which acids precipitate the xyloidin slightly modified.
10. When heated it melts, and is charred at a very low temperature. When distilled in a retort it leaves about one-fourth of its weight of charcoal, and furnishes a brown liquid containing much acetic acid. See Ann. de Chim. et de Phys. lii. 290.

SECTION VI.—OF FUNGIN.

This is a name given by Braconnot to the fleshy part of mushrooms, which he considers as a peculiar vegetable principle. It approaches in its chemical characters so closely to woody fibre, that perhaps it would be better to consider it merely as a variety of that substance. Fungin is the substance which remains after the mushroom has been deprived of every thing soluble, either in water or alcohol. It is distinguished by the following properties:—

It is white, soft, and insipid, possesses but little elasticity, and divides easily between the teeth. In this state it constitutes a nourishing article of food.

It is insoluble in water, alcohol, ether, and oils.

Alkalies have but little action on fungin; a property which distinguishes it from woody fibre, which is very readily dissolved even by a weak alkaline ley. Yet when boiled in a concentrated alkaline ley, fungin is partly dissolved, and a saponaceous liquid is obtained from which the acids throw down a flocky matter.

Ammonia dissolves a little of it when digested over fungin, and on exposure to the air allows it to precipitate again in the state of white flocks.

Diluted sulphuric acid has no action on it; but concentrated sulphuric acid chars it, while acetic and sulphurous acid are evolved.

Muriatic acid, at first, seems to have no action on it, even though assisted by heat; but it gradually dissolves it, and converts it into a gelatinous matter soluble in water. Potash dropped into the solution throws down the fungin, probably altered in its properties.

Chlorine gas converts it into a yellow matter which has an acrid taste while wet, but which it loses when dried. This yellow substance is a compound of fungin, muriatic acid, and a kind of adipo-resinous matter.

Weak nitric acid disengages azote from it. When distilled with 6 times its weight of nitric acid it becomes yellow, swells considerably, and effervesces at first very much; but the violent action soon subsides. Prussic acid is formed by this process, together with a considerable quantity of oxalic acid, two fatty bodies resembling tallow and wax, and a small quantity of yellow-bitter principle, and a yellow resinous-looking substance.

When put into infusion of nutgalls it absorbs the greatest part of the tannin contained in that liquid, and acquires a fawn colour.

When mixed with water and left to spontaneous putrefaction it emits, at first, the smell of putrid cheese; but this smell soon goes off. The liquid covering it, after an interval of three months, was neither acid nor alkaline; but held in solution a mucilaginous matter. The fungin still retained its original shape. When washed it is easily reduced to a pulp, which may be kneaded between the fingers, but has not the elastic consistence of gluten.

Fungin, when dry, burns with vivacity, and leaves a white ash, consisting chiefly of phosphate of lime.

38 parts being distilled, yielded 8 parts of a brown empyreumatic oil, and 11½ parts of a liquid containing an excess of ammonia, and holding in solution acetate of ammonia mixed with oil. The charcoal in the retort weighed 10 parts.* When fungin was distilled by Vauquelin, the liquid which he obtained contained ammonia; but it reddened vegetable blues, and, therefore, contained an excess of acetic acid, as is the case with the liquid obtained from the distillation of wood.†

SECTION VII.—OF DIASTASE.

This is a name given by MM. Payen and Persoz, to a substance which they extracted from malted barley, and which deserves to be known on account of the important purposes in domestic economy to which it may be applied.‡ It may be obtained in the following manner:—

Ground malt is macerated in cold water for some time. The whole is then to be subjected to pressure, and the liquid which flows out is to be filtered, and then heated to the temperature of 158°. This temperature is sufficient to coagulate, and cause to separate the greatest part of an azotized matter which exists in the liquid. The liquid being filtered again is to be mixed with a sufficient quantity of alcohol to throw down the *diastase*, while the sugar, colouring matter, and the residue of the azotized substance, remain in solution. To obtain the diastase pure, it should be again dissolved in water, and thrown down by alcohol; and this ought to be repeated two several times.

Diastase thus obtained is solid, white, amorphous, insoluble in alcohol, but soluble in water and dilute alcohol. Its aqueous solution possesses neither acid nor alkaline qualities, and has little taste. It is not precipitated by diacetate of lead. Abandoned to itself it becomes acid, and the more rapidly the higher the temperature. When heated to 150° or 167° with flour or starch, it has the remarkable property of detaching the envelopes from the amidin. With this last substance it enters into combination, and causes it to form a solution in water, while the amylin separates, either falling to the bottom or floating on the surface. It was in consequence of this property of separating the two constituents of starch from each other, that MM. Payen and Persoz gave it the name of *diastase*.§

Diastase exists in the seeds of malted barley, oats, and wheat. It exists neither in the roots nor stems of potatoes, but only in the tubercles near the places from which the shoots proceed. It is there associated with an azotized substance which, like diastase, is soluble in water, and insoluble in alcohol; but which differs in not being coagulated in water, by a temperature between 150° and 167°,

* Braconnot, Ann. de Chim. lxxix. 267. † Ann. de Chim. lxxxv. 12.

‡ Ann. de Chim. et de Phys. liii. 73.

§ From διαστημι, *to separate*.

in not acting on starch, in being precipitated from its solutions by diacetate of lead, and in being in a great measure eliminated by alcohol, before the precipitation of diastase. The different species of corn and tubers of the potatoe do not contain diastase before they have germinated.

The solution of diastase, whether it be pure or contain sugar, separates amidin from all starchy substances containing it. Such is its energy, that one part of it is sufficient to render soluble the interior portion of two thousand parts of starch, and to convert it into sugar.

To prepare, upon a large scale, what has been called *dextrine*, or the sweet liquid of Biot, we take 10 parts of ground malt for 100 of flour; and when the object is to obtain a syrup, the temperature is kept up for three hours, at between 158° and 167°. When we wish to have the dextrine with as little sugar as possible, we raise the liquor to the boiling temperature, which puts an end to the action of the diastase. The details of the process are as follows:—

We put into a caldron about 850 lbs. of water. When the temperature of the water has risen to 86°, the ground malt is added, and we continue to raise the heat till the temperature becomes 140°. Then all the flour (220 lbs.) is added, and the whole well mixed. When the temperature has risen to 158°, we should endeavour to keep it steady at that point, or at least not to allow it to cool below 150°, nor to rise above 167°. This is easily done if the bath be heated by steam, introduced by means of a pipe, which may be stopped at pleasure by turning a stop-cock.

In 20 minutes the liquid, at first milky and thick, becomes more transparent: and from being viscid and thready as at first, it becomes almost as fluid as water. When this happens, we suddenly raise the temperature to 212°. The whole is then left at rest, the clear portion is drawn off, filtered and evaporated either by steam or by means of a bath heated to 230°. During the evaporation the scum is to be removed. When sufficiently concentrated, it is poured into a receiver of tin plate or wood. On cooling, it coagulates into an opaque jelly.

While hot, if it be mixed with yeast and kneaded into the dough, it serves well for the preparation of bread.

If we spread it out in thin layers and dry it in the air, or by means of a stove, we obtain dry *dextrine*, which being reduced to powder, may be introduced into all kinds of pastries, chocolate, bread, &c.

The syrup of dextrine may be employed also for preparing spirits by fermentation, and for many other purposes which have been pointed out at great length by Payen and Persoz.

We are indebted to M. Guerin-Varry, for a set of elaborate experiments on the action of diastase on potatoe starch.* I shall state here the principal facts which he has ascertained.

1. One part of diastase dissolved in 30 parts of water, being

* Ann. de Chim. et de Phys. lx. 32.

placed in contact with 408 parts of potatoe starch out of contact of the air, did not act upon it in sixty-three days, in a temperature varying from 68° to 79°.

2. Two parts of diastase did not burst the globules of 3 parts of potatoe starch, though kept in a heat but little lower than that which bursts the starch globules.

3. Diastase liquefies and converts into sugar starch mucilage, without the absorption or disengagement of any gas. The reaction takes place even *in vacuo.*

4. One hundred parts of starch in the state of mucilage, with 39 times their weight of water, and then mixed with $12\frac{1}{4}$ parts of diastase dissolved in 40 parts of water, formed 86·91 of sugar.

5. Between the temperature of 23° and 10°, 4′ no sugar is formed by the action of these bodies on each other.

6. The circumstances most favourable for producing the greatest quantity of sugar, are a slight excess of diastase or malt, about 50 parts of water for 1 of starch, and a temperature between 140° and 149°.

7. Diastase does not convert gum into sugar. Nor does it act on common sugar or upon yeast.

8. A solution of diastase is rapidly decomposed whether it be left in contact with the air or not.

SECTION VIII.—OF OLIVILIN.

This substance was discovered by Pelletier in 1816, while examining an exudation from the *oliva Europea*, or *common olive tree* in the southern parts of Italy.* In Calabria, this exudation bears the name of *Lecca gum*, from a town in that country near which it occurs abundantly. It was known to the ancients, who employed it in dressing sores.

Olivilin may be obtained by the following process:—

Digest the so called gum of the olive in ether, in order to remove a resinous matter which it contains. From the undissolved portion absolute alcohol dissolves the olivilin, which is deposited in crystals on evaporating the solution.

It is white and brilliant, and has the aspect of starch. It has no smell; but its taste is at once sweet, bitter and aromatic. It melts when heated to 158°. When allowed to cool it puts on the appearance of a resin, and is a non-conductor of electricity. When heated in a retort, it gives out no ammonia.

It is but little soluble in cold water, and requires 32 times its weight of boiling water to dissolve it. When the decoction is allowed to cool, it becomes milky and remains long in that state. Boiling alcohol dissolves any quantity of it whatever, but it is much less soluble in cold alcohol. Ether does not dissolve it at all. Both fixed and volatile oils dissolve a small quantity of it when assisted by heat, but it is again deposited when the liquids are allowed to cool.

* Ann. de Chim. et de Phys. iii. 105, and li. 196.

Dilute sulphuric acid does not dissolve it, and concentrated acid chars it. Nitric acid dissolves it cold, and assumes a red colour. When the solution is heated it becomes yellow, and oxalic acid and carbazotic acid are formed. Acetic acid dissolves it and the olivilin is not precipitated from this solution by water. The alkalies dissolve it with facility and without altering its nature. The aqueous solution of olivilin is precipitated by acetate of lead, and the precipitate is soluble in acetic acid.

Its constituents, determined by the analysis of Pelletier, are

Carbon	63·84 or 6	atoms = 4·5	or per cent.	63·72
Hydrogen	8·06 or 4½	atoms = 5625	— —	7·96
Oxygen	28·10 or 2	atoms = 2	— —	28·32
	100·00	7·0625		100·00

SECTION IX.—OF COLUMBIN.

This principle was discovered in 1830 by M. Wittstock, in *Columbo root.** Two different vegetables yield a root, which is known in commerce by the name of columbo root. One of them is called *African columbo*, and the other *American columbo*, or *Marcetta columbo*, pointing out by these names the country from which the roots come. The African columbo is the root of the *cocculus palmatus*, which is abundant in the forests of Mozambique. The plant that furnishes the American columbo, is still unknown to botanists.

Columbin was obtained by Wittstock† in the following manner :—

The root previously pulverized is digested in ether till every thing soluble is taken up. When the ethereal solution is abandoned to spontaneous evaporation, the columbin is deposited in crystals.

But by this process only a minute quantity of columbin is obtained. To procure it in greater quantity, let the root be treated twice or thrice successively with alcohol, of the specific gravity 0·835. Mix these solutions, distil off ¾ths of the alcohol, and allow the residual liquid to remain at rest for some days. Crystals are deposited which may be collected by throwing the whole on a cloth and allowing the liquid portion to pass through. Let these crystals be washed in cold water, dissolved in alcohol, and the solution digested with ivory black and filtered. When the solution thus treated is concentrated, it deposits pure crystals of columbin. The mother liquor still contains abundance of the same principle. Let it be mixed with pounded glass and evaporated to dryness, stirring it constantly when it begins to become concrete. Digest this powder mixed with glass in ether, which dissolves wax, fatty matter, and columbin. Distil off the ether, and digest the residue in boiling acetic acid, which will dissolve the columbin and leave the other substances. If the

* Poggendorf's Annalen, xix. 298. It appears, from a note in the *Journal de Pharmacie*, xvii. 80, that M. Planche had obtained columbin as early as 1811; though not in a state of purity.

† Jour. de Pharmacie, xvii. 77.

acid be evaporated the columbin separates in crystals. Eight ounces of columbo root furnished only 60 grains of columbin.

It crystallizes in rhombic prisms. It is destitute of smell, but has a very bitter taste. When heated it melts, and assumes the appearance of wax. When distilled it yields no ammonia. It possesses neither the properties of an acid nor alkali.

At the ordinary temperature of the atmosphere, it is but very little soluble in water, alcohol, or ether. Yet these liquids dissolve enough of it to acquire a bitter taste. Boiling alcohol of the specific gravity 0·835 dissolves from $\frac{1}{40}$ to $\frac{1}{30}$th of its weight of it. It dissolves also, though very sparingly in volatile oils. Sulphuric acid dissolves it, assuming first a yellow and then a red colour. When water is added to the solution the columbin is precipitated under the form of a rusty yellow matter. Nitric acid of 1·25 dissolves it when assisted by heat, without decomposing it, and the columbin is partly precipitated by the addition of water.

Boiling acetic acid of the specific gravity 1·04 is the best solvent of columbin, and when the solution is concentrated the columbin is deposited in regular crystals. Muriatic acid has very little action on columbin. It dissolves unaltered in the caustic alkalies, and is precipitated again by the addition of an acid.

It was analyzed by Liebig, who obtained

Carbon	65·45 or	12 atoms =	9	or per cent.	64·87
Hydrogen	6·18 or	7 atoms =	0·875	— —	6·32
Oxygen	28·37 or	4 atoms =	4	— —	28·81
	100·00*		13·875		100·00

CHAPTER VI.

OF GUMS.

The name *gum* was originally applied to a thick transparent tasteless fluid which exudes from various trees and plants, and which gradually concretes into a solid substance when left exposed to the air; but easily softens again when moistened with water. The gum most commonly used in this country is known by the names of *gum arabic* and *gum senegal*. It exudes from the *acacia vera*, *acacia arabica* and *acacia senegal*, but many other plants yield it, as the apple-tree, plum-tree, cherry-tree, &c. Many seeds of plants, *lint-seed* for example, when macerated in water, render the liquid thick and adhesive, converting it into what is called *mucilage*. When this mucilage is evaporated to dryness, it leaves a translucent matter behind it, similar in its properties to gum, and usually distinguished by the same name.

* Poggendorf's Annalen, xxi. 31.

For the most careful examination of the different substances usually classed among gums, we are indebted to M. Guerin-Varry, who has published some elaborate papers on the subject.* They may without inconvenience be arranged under three different genera: namely, *arabin*, *bassorin*, and *cerasin*. These will form the subject of the following Sections:—

SECTION I.—OF ARABIN.

This name was applied by M. Chevreul, because *gum arabic*, the best known and most employed of all the gums, consists almost entirely of *arabin*.

Gum arabic comes to this country from the Levant; but its use has been in a great measure superseded by gum senegal. It is in small rounded drops or tears, either colourless or having a light yellow colour. Hard and easily pounded. It breaks with a vitreous fracture, and has a specific gravity of 1·355.† When moistened it reddens litmus paper, and is said sometimes (though I have never met with it in that state) to have an acid taste. According to the experiments of M. Guerin-Varry, gum arabic dried *in vacuo*, at the temperatnre 257°, loses 17·6 per cent. of its weight. Its constituents, according to the analysis of the same chemist, are

Arabin	79·4
Ashes	3·0
Water	17·6
	100·0

The ashes consist of carbonates of potash and lime; a trace of phosphate of lime, chloride of potassium, oxide of iron, alumina, silica and magnesia.

The characters of *arabin* are the following:—

It is colourless, tasteless, and destitute of smell. Fracture vitreous. Transparent. Friable when dry; but very tough when allowed to imbibe water. When heated to between 282° and 392° it softens, and may be drawn out into threads.

When kept in a dry atmosphere, it does not alter its nature; but it becomes acid when kept long in a moist atmosphere.

It is insoluble in alcohol, incrystallizable and incapable of undergoing the vinous fermentation.

At 68° an aqueous solution of arabin, containing more than 17·75 parts of arabin to 100 of water, will not filter through paper. Nor will it filter at 212° if it contains more than 23·54 per cent. This solution is known by the name of *mucilage*. It is very viscid and glutinous, and may be employed as a paste. It is commonly used by the calico-printers to thicken their colours and mordants, to prevent them from spreading on the cloth. Mucilage may be kept for

* Ann. de Chim. et de Phys. xlix. 248.

† Its specific gravity, as determined by Herberger, varies from 1·4606 to 1·5256. Jour. de Pharmacie, xx. 411.

years, without undergoing much change; but at last it becomes acid.

When boiled with sulphuric acid in the usual way, it is converted into a sugar, which does not ferment when mixed with yeast, and which, therefore, is different from starch sugar, and seems to approach manna.

100 parts of arabin, when heated with 400 parts of nitric acid, of the specific gravity 1·339, form 16·88 parts of mucic acid, together with a little oxalic acid.

When silicated potash solution is dropt into an aqueous solution of arabin, a white flakey precipitate falls, even when the mucilage is very dilute. This precipitate consists of gum, silica, and potash, and there remains in solution a combination of gum and potash. By this reagent a very minute quantity of arabin, dissolved in water, may be discovered.

When a concentrated solution of perchloride of iron is dropt into mucilage, the whole becomes a brown semitransparent jelly, which is not readily dissolved in water.

We have three analyses of arabin. The first by Guy-Lassac and Thenard, the second by Berzelius, and the third by M. Guerin-Varry. The following table exhibits the results obtained by these chemists:—

	Gay-Lussac & Thenard.*	Berzelius.†	Guerin-Varry.‡
Carbon . .	42·23	42·682	43·81
Hydrogen . .	6·93	6·374	6·20
Azote . .	—	—	0·14
Oxygen . .	50·84	50·944	49·85
	100	100	100

These numbers approach pretty nearly to each other. As M. Guerin-Varry dried his arabin at a higher temperature than the other experimenters, we see the reason why his product of carbon exceeds theirs. The azote found alone by Guerin-Varry is in so small a quantity, that it cannot be considered as belonging to the constitution of arabin. The preceding numbers lead to the following atomic proportions for the constituents of arabin:—

12 atoms carbon	= 9	or	per cent.	42·11
11 atoms hydrogen	= 1·375	—	—	6·43
11 atoms oxygen	= 11·000	—	—	51·46
	21·375			100·00

Now, this is precisely the constitution of common sugar in crystals.

Such are the characters and such the composition of pure arabin. It will be proper now to mention the principal gums that consist altogether or chiefly of arabin.

* Recherches, Physico-Chimiques, ii. 290. † Annals of Philosophy, v. 270.
‡ Ann. de Chim. et de Phys. xlix. 260.

1. *Gum arabic.* It becomes colourless when exposed to the sun, or when treated with chlorine water. Its constituents and specific gravity have been given above. When alcohol is boiled over gum arabic, it extracts bimalate of lime, chlorides of potassium and calcium, acetate of potash and chlorophyllin, together with a matter analogous to wax.

2. *Gum senegal* has been shown by Perottet and Guillemin to be the produce of the *acacia verek.** It comes from the west coast of Africa, and, being cheaper and equally useful, it has nearly supplanted gum arabic in this country. Its specific gravity, as determined by M. Guerin-Varry, is 1·436.† It occurs in much larger pieces than gum arabic, sometimes even as large as the fist, having an ovoid shape, and often hollow. It has a darker colour than gum arabic, but its properties are similar.

100 parts of water, at 68°, dissolve 18·49 parts of it, while 100 parts of boiling water dissolve 24·17 parts.

Boiling alcohol, chlorine, and sulphuric and nitric acids act upon it as on gum arabic. 100 parts of it, heated with 500 parts of nitric acid, furnish 16·7 parts of mucic acid, together with a little oxalic acid.

Its constituents, determined by the analysis of M. Guerin-Varry, are

Arabin	81·1
Ashes	2·8
Water	16·1‡
	100

The ashes are precisely similar to those of gum arabic.

3. *Mucilage of lintseed.* When lintseed is digested in hot water, and the solution obtained concentrated in a porcelain vessel over the water-bath, we obtain this mucilage. When dried it forms brown brittle crusts, having a peculiar smell, which Vauquelin compared to that of osmasome. It reddens vegetable blues, and thickens water, when dissolved in it. In alcohol it is insoluble. It does not crystallize, is neither precipitated by infusion of nutgalls, nor chlorine, and is not coloured blue by iodine, provided the lintseed from which it was procured was unadulterated.

When this mucilage is put into water, it divides into two parts, the one soluble, the other insoluble. The insoluble portion, when treated with nitric acid, does not form mucic acid. It does not, therefore, belong to any of the genera of gum. But its nature has not yet been ascertained.

The composition of mucilage from lintseed, according to the analysis of Guerin-Varry, is

* Jour. de Pharmacie, xix. 250.

† According to Herberger, it varies from 1·5686 to 1·6511. Jour. de Pharmacie, xx. 411.

‡ According to Herberger, it loses at 212° 19½ per cent., but the gum is a little altered. Jour. de Pharmacie, xx. 410.

Soluble gum	52·70
Insoluble	29·89
Ashes	7·11
Water	10·30
	100·00

The ashes contain carbonates of potash and lime, phosphate of lime, chloride of potassium, sulphate of potash, oxide of iron, alumina, and silica.

M. Guerin-Varry has subjected lintseed mucilage to an elementary analysis, by means of oxide of copper, and obtained

Carbon	34·30
Azote	7·27
Hydrogen . . .	5·65
Oxygen . . .	52·78
	100·00

As the soluble constituent is arabin, it is obvious, that the azote must come from the insoluble constituent, the nature of which has not been ascertained. These numbers lead to

12 atoms carbon
1 atom azote
12 atoms hydrogen
14 atoms oxygen.

Now, as arabin is composed of C^{12} H^{11} O^{11}, it is obvious, that the insoluble matter of lintseed mucilage must consist of Az H O, provided the analysis be correct.

SECTION II.—OF BASSORIN.

The substance called *bassorin* was first noticed by Vauquelin, in a gum from Bassora. When this gum is treated with water, the bassorin remains in a gelatinous form.* It was afterwards found by Bucholz to constitute a portion of gum tragacanth,† and by John, of cherry-tree gum.‡ Its properties were first accurately investigated by M. Guerin-Varry.§

To obtain bassorin, we have nothing more to do than to wash gum bassora with cold water, till every thing soluble has been taken up. The residue is then allowed to drain, dried upon a cloth, and finally freed from water, by placing it in a silver cup on a water-bath, till all the mixture is dissipated.

It is solid, colourless, semitransparent, insipid, inodorous, and incrystallizable. It is tough, and, consequently, not easily reduced to powder. It is insoluble in water, whether cold or hot; but swells up, and becomes like jelly. It is insoluble in alcohol; and, like arabin, is incapable of undergoing the vinous fermentation.

100 parts of it, when heated with 1000 parts of nitric acid, formed 22·61 parts of mucic acid, and at the same time some oxalic acid.

* Ann. de Mus. d'Hist. Nat. xvi. 167. † Taschenb. 1815, p. 61.
‡ Schweigger's Jour. vi. 375. § Ann. de Chim. et de Phys. xlix. 266.

When treated with sulphuric acid, it forms a crystallizable sugar, which, according to the experiments of M. Guerin-Varry, is incapable of being made to undergo the vinous fermentation.

The constituents of bassorin, as determined by the analysis of M. Guerin-Varry, are

Carbon	37·28 or 10 atoms =	7·5	or per cent.	37·74
Hydrogen	6·85 or 11 atoms =	1·375	— —	6·91
Oxygen	55·87 or 11 atoms =	11·00	— —	55·35
	100·00	19·875		100·00

It will now be proper to notice the principal gums which contain bassorin.

1. *Gum Bassora.* Its specific gravity is 1·359. Its colour is yellowish-white. It is imported into France; but I am not aware of its being employed in this country.

Its constituents, according to the analysis of M. Guerin-Varry, are

Water	21·89
Ashes	5·60
Arabin	11·20
Bassorin	61·31
	100·00

It yields to alcohol chlorophyllin, wax, acetate of potash, chloride of calcium, and bimalate of lime.

2. *Gum tragacanth.* This gum is the produce of the *astragalus tragacantha*, a thorny shrub, which grows in Candia, and other islands of the Levant.* The gum is said to exude about the end of June from the stem and larger branches, and soon dries in the sun. It is in the state of hard vermiform pieces, of a white colour, and not nearly so transparent as gum arabic. Its specific gravity is 1·384. When heated to a temperature between 104° and 122°, it becomes more easily pulverizable. When put into water it gradually swells, and forms a thick mucilage. When this mucilage is left to itself for some weeks, it gives out a smell similar to that of starch placed in the same circumstances, and to that of butyric acid. The insoluble portion of this gum becomes blue by iodine, and therefore contains starch.

The constituents of gum tragacanth, according to the analysis of M. Guerin-Varry, are

* According to Sieber, gum tragacanth is not brought from Crete, but from Asia Minor, and chiefly from Mount Ida. The plant which yields it is the *astragalus verus*. It grows between 2500 and 3000 feet up the mountain. It is from Smyrna that it is imported into Europe.

There is obviously some confusion in this statement. Ida is a mountain in Candia. Tournefort gives a description of the plant which yields tragacanth under the name of *limonium creticum*, and assures us that he witnessed the gum tragacanth exuding from it spontaneously. See Tournefort's Voyage, i. 58.—English translation.

Water	11·1
Ashes	2·5
Arabin	53·3
Bassorin and starch . .	33·1
	100·0

3. *Gum kuteera.* This gum, according to Dr Roxburgh, is the produce of the *sterculio urens*,* a tree which grows in Hindostan. Having some resemblance to gum tragacanth, great quantities of it were imported into Great Britain, about the beginning of the present century, for the use of the calico-printers, but it was found not to answer as a substitute for gum senegal. Gum kuteera is in loose wrinkled drops or pieces, without smell or taste, and mostly transparent. In water it slowly forms a pulp or jelly, like gum tragacanth; but if pounded well in a mortar, and then boiled in water for 15 minutes, with constant agitation, it is said to be completely dissolved. A tea spoonful of its powder gives to water the consistence of capillaire. In India it enters into the composition of some varnishes; it is used by the calico-printers, and is one of the ingredients of a famous medicine for horses among them.†

Some years ago I received from a calico-printer of Glasgow a specimen of a gum, which he found in considerable quantity in a calico-printing establishment, which he had purchased in the neighbourhood of Perth. It was in large brown-coloured and wrinkled translucent pieces, having a certain degree of softness; so that they could not be pounded in a mortar. When put into water, they did not dissolve; but gradually imbibed the water, and swelled out into a jelly, so nearly colourless, that its presence at the bottom of the vessel containing water was not perceptible, till the water was agitated by moving the vessel. When boiled for some hours with water, this jelly completely dissolved. But the water was not mucilaginous, like a solution of gum arabic, nor had it the least adhesive property. When two pieces of paper, besmeared with this solution, were laid upon each other, and allowed to dry, they did not cohere together, but separated just as if the pieces of paper had been moistened by pure water. Thus this substance, though resembling gum in its appearance, possessed none of the properties of that substance, and could not be employed to thicken acids or colours intended to be printed on the cloth.

I do not know how far this substance agrees with bassorin; and not being acquainted with the plant from which it was obtained, though there is reason to suspect that it came from India, I can give no farther account of it. I mention it merely to make any person, who may be going to India, and is possessed of chemical knowledge, aware of the circumstance. Because this peculiar substance, if it could be discovered again, is highly worthy of investigation.

* Nicholson's Jour. xxvii. 70. † Cowie; Nicholson's Jour. vii. 301.

SECTION III.—OF CERASIN.

This name has been given to a substance in *cherry-tree gum* which remains undissolved when that gum is treated with cold water. When obtained by this process, and dried, it possesses the following properties :—

It is solid, tasteless, semitransparent, insipid, inodorous, incrystallizable, and easily pulverized.

It is insoluble in alcohol. Does not undergo the vinous fermentation. Swells a little in cold water, but does not dissolve. When boiled in water, it is converted into *arabin*.

It is isomeric with *arabin*, as might be expected from its easy conversion. Probably arabin was originally in the same state with cerasin, but rendered soluble in cold water by the great heat to which it is exposed, or in which it is produced. The composition of cerasin was found by M. Guerin-Varry as follows :—

Water	8·4
Ashes	1·0
Cerasin	90·6
	100·0

15·43 grains of it being boiled for six hours in 122 cubic inches of water, adding water as it evaporated, was completely dissolved. Being evaporated to dryness in a platinum capsule, and analyzed, it was found composed of

Water	8·402
Ashes	1·011
Arabin	90·587
	100·000

Numbers almost coinciding with the former, arabin being substituted for cerasin.

The gum given out by the cherry-tree, apricot, plum, peach, and almond, consists of a mixture of arabin and cerasin.

The following table exhibits the specific gravity of these gums, as determined by M. Guerin-Varry :—

Cherry-tree gum . . .	1·475
Apricot	1·469
Plum	1·491
Peach	1·421
Almond	1·530

The following table exhibits the composition of these gums, as analyzed by the same chemist :—

	Cherry-tree.	Apricot.	Plum.	Peach.	Almond.
Water . .	12	6·82	15·15	14·21	13·79
Ashes . .	1	3·33	2·62	3·19	2·97
Arabin . .	52·1	89·85	82·83	82·60	83·24
Cerasin . .	34·9				
	100	100	100	100	100

The following table exhibits the quantity of mucic and oxalic acid furnished by 100 parts of these gums, when treated with 400 parts of nitric acid:—

Cherry-tree gum . . .	15·74
Apricot	15·97
Plum	15·78
Peach	14·99
Almond	15·03

SECTION IV.—OF CALENDULIN.

Calendulin was obtained by Geiger from the flowers of the *Calendula officinalis*, or *Marygold*.* The process which he employed was the following:—

The flowers and leaves of *marygold* were digested in alcohol, and the solution was evaporated to the consistence of an extract. This extract was digested, first in ether, which dissolved a substance analogous to wax; it was then digested in water. There remains a mucilaginous substance, almost insoluble in water, whether boiling or cold. This is the calendulin. When dried it is yellowish, translucent, and brittle. When moistened with water it swells up, and is again converted into mucilage. In the impure state in which it exists in the plant, it is soluble in hot water, but during the cooling the liquid assumes the form of a jelly.

Calendulin is insoluble in the dilute acids, but it dissolves in concentrated acetic acid. Dilute solutions of the caustic alkalies dissolve it; but it is insoluble in the alkaline carbonates, and in lime water. It dissolves easily in strong and absolute alcohol; from the former, it is deposited in the form of a jelly; and from the latter, in dry pellicles. Infusion of nutgalls does not precipitate it. It is insoluble in ether, and in the fixed and volatile oils.

SECTION V.—OF SAPONIN.

This substance was discovered in 1832, by M. Bussy,† while examining a root sent him by the *Societé d'Encouragement*, which it seems was capable of being employed as a substitute for soap. The root was considered to belong to the *Gypsophila struthium*, a plant which grows spontaneously in Hungary, Greece, and several countries of the east. Bucholz had already, in 1811, described a substance from the *saponaria officinalis*, to which he gave the name of *saponin*.‡ And this substance had been further examined by Braconnot.§ Bussy applied the same name to the substance extracted from the root of the *Gypsophila struthium*, doubtless because he conceived it to be the same with the saponin of Bucholz and Braconnot.

Saponin may be obtained from the root of *saponaria officinalis*, or of *gypsophila struthium*, by the following process:—

* Disser. de Calendula officinali. Heidelberg, 1819.
† Jour. de Pharmacie, xix. 1. ‡ Taschenbuch, 1811, p. 33.
§ Jour. de Phys. lxxxiv. 287.

The root, previously reduced to powder, is boiled for a few minutes with alcohol of the specific gravity 0·837. The solution being filtered and left to cool, deposits the saponin, which is pressed between folds of blotting paper and dried.

It is a white friable mass, without any appearance of crystallization. Its taste is very acrid, and it continues long in the mouth. When in powder it acts as a powerful sternutatory.

In water it dissolves in all proportions like gum. The aqueous solution froths, when agitated, like a solution of soap; and 1 part of saponin is capable of communicating this property to 1000 parts of water.

Weak alcohol is a good solvent of saponin, and the solubility diminishes as the strength of the liquid increases. But saponin is still soluble in alcohol of the specific gravity 0·817. Ether has no action on saponin; but if the root has not been digested in ether before the alcoholic decoction is made, the ether dissolves a portion of fatty matter with which the saponin in that case is mixed.

When saponin is heated in a retort or glass tube it swells up and blackens, without being volatilized, but gives out a considerable quantity of acid empyreumatic oil. In the air it burns with flame, swelling up at the same time.

Dilute acids, when added to a solution of saponin, occasion no sensible change. Muriatic and acetic acids augment its solubility in alcohol.

When 3 parts of saponin are digested with 5 parts of nitric acid of the specific gravity 1·33, it is partly coagulated like an aqueous solution of albumen. After this the action of the acid becomes rather violent, the matter swells up, and a yellow matter, having a resinous appearance, swims upon the surface. This matter is friable, slightly bitter, soluble in alcohol; and when the alcoholic solution is evaporated, crystals are deposited. This substance is an acid, and appears to have considerable analogy to carbazotic acid.

Alkalies have no action on saponin. Barytes water poured into a solution of 1 part of saponin in 4 parts of water, occasions a white precipitate, soluble in water, and in an excess of the solution of saponin.

Neither lime water nor acetate of lead occasion any precipitate. But diacetate of lead occasions a copious precipitate.

According to the analysis of Bussy, saponin is composed of

Carbon	51·0	or 26 atoms =	19·5	or per cent.	50·82
Hydrogen	7·4	or 23 atoms =	2·875	— —	7·49
Oxygen	41·6	or 16 atoms =	16·0	— —	41·69
	100·0		38·375*		100

M. Bussy poured subacetate of lead into a solution of saponin. When he stopped the addition, as soon as a precipitate ceased to fall, the compound formed consisted of

* A short account of saponin has been given in page 51 of this Volume. There is a typographical error in that place, 79·375 being substituted for 38·375, the true number. We have added the observations that follow, as calculated to throw some light on the true atomic weight of saponin.

Saponin . . .	72·8 or 37·43
Oxide of lead . .	27·2 or 14
	100·0

When he added an excess of subacetate of lead, the compound formed was composed of

Saponin . . .	61·6 or 22·45
Oxide of lead . .	38·4 or 14
	100·0

The first of these compounds gives 37·43 for the atomic weight of saponin, which approaches the preceding formula. The second, unless it be a disalt, would lead to the formula

15 atoms carbon	= 11·25	or per cent.	51·43
13 atoms hydrogen	= 1·625	— —	7·43
9 atoms oxygen	= 9·00	— —	41·14
	21·875		100·00

This formula would make the atomic weight 21·875, which comes pretty near 22·45, the number resulting from the second compound of saponin and oxide of lead. I am disposed to prefer the first formula.

CHAPTER VII.

OF GLUTINOUS SUBSTANCES.

If wheat flour be kneaded into a paste with a little water, it forms a tenacious, elastic, soft, ductile mass. This is to be washed cautiously, by kneading it under a small jet of water till the water no longer carries off any thing, but runs off colourless; what remains behind is called *gluten*. It was discovered in 1742 by Beccaria, an Italian philosopher, to whom we are indebted for the first analysis of wheat flour.*

Gluten, when thus obtained, is of a grey colour, exceedingly tenacious, ductile, and elastic, and may be extended to twenty times its original length. When very thin, it is of a whitish colour, and has a good deal of resemblance to animal tendon or membrane. In this state it adheres very tenaciously to other bodies, and has been often used to cement together broken pieces of porcelain. Its smell is peculiar. It has scarcely any taste, and does not lose its tenacity in the mouth. In the air it assumes a brown colour, and becomes as it were covered with a coat of oil.

When exposed to the air, it gradually dries; and when completely

* Collect. Academ. xiv. 1.

dry, it is pretty hard, brittle, slightly transparent, of a dark brown colour, and has some resemblance to *glue*. It breaks like a piece of glass, and the edges of the fracture resemble in smoothness those of broken glass; that is to say, it breaks with a *vitreous* fracture.

Fresh gluten imbibes water, and retains a certain quantity of it with great obstinacy. To this water it owes its elasticity and tenacity. When boiled in water it loses both these properties.

When kept moist, it very soon begins to decompose, and to undergo a species of fermentation. It swells, and emits air-bubbles, which Proust has ascertained to consist of hydrogen and carbonic acid gases.* It emits also a very offensive odour, similar to what is emitted by putrefying animal bodies. Cadet kept gluten in a vessel for a week in a damp room. Its surface became covered with byssi, the fermentation just mentioned had commenced, and the odour was distinctly acid. In 24 days, on removing the upper crust, the gluten was found converted into a kind of paste, of a greyish white colour, not unlike bird-lime. In that state he gave it the name of *fermented gluten*.† If the gluten be still left to itself, it gradually acquires the smell and the taste of *cheese*. This curious fact was first ascertained by Rouelle, junior. In that state it is full of holes, and contains the very same juices which distinguish some kinds of cheese. Proust ascertained that it contains ammonia and vinegar; bodies which Vauquelin detected in cheese: and ammonia robs both equally of their smell and flavour.‡

Gluten has been resolved by modern chemists into four distinct principles; namely, *albumen*, *emulsin*, *mucin*, and *glutin*. These will constitute the subject of the four following Sections.

SECTION I.—OF ALBUMEN.

When fresh gluten of wheat is digested in hot alcohol till every thing soluble is taken up, a bulky substance of a greyish colour remains, which constitutes what has been called *vegetable albumen*. When thus obtained, it possesses the following properties:—

1. Soluble in water. But when the solution is heated, the albumen coagulates and becomes insoluble.
2. It is insoluble in alcohol and ether.
3. It has not the property of cementing pieces of paper or cloth together, as is the case with a solution of gum, or of starch.
4. When dry, it is opaque, and has a white, grey, brown, or even a black colour, according to circumstances.
5. It is readily soluble in caustic alkalies. The solution may be rendered slightly acid without any precipitation taking place. But a great excess of acid throws down a precipitate, which is a compound of albumen and the acid employed. This precipitate is but little soluble in water; and when dissolved in that liquid, it is precipitated again by acids, prussiate of potash, corrosive sublimate, and infusion of nutgalls.

* Jour. de Phys. lvi. 108. † Ann. de Chim. xli. 315.
‡ Proust, Jour. de Phys. lvi. 100.

6. It is not dissolved by the alkaline carbonates, and after having been coagulated, it does not dissolve even in caustic ammonia. If we add carbonate of ammonia to a saturated solution of albumen in caustic potash, a portion of the albumen precipitates, but is again redissolved by adding a sufficient quantity of water. Carbonate of ammonia is the best precipitant of albumen from an acid solution. The albumen falls down in white flocks. Caustic ammonia throws down nothing from such a solution.

7. When earthy or metalline salts are mixed with a solution of albumen in caustic potash, the albumen combines with the base of the salt, and generally forms with it an insoluble compound which precipitates. When a persalt of iron is employed as a reagent in this way, the precipitate, after being washed and dried, has a deep red colour. The protosalts of iron throw down a white precipitate, which becomes yellow by exposure to the air, and the salts of copper throw down a pale bluish-green precipitate.

SECTION II.—OF EMULSIN.

This name has been given by Wöhler and Liebig to a peculiar substance which exists in almonds, and which has the curious property of decomposing amygdalin, and of forming hydrocyanic acid, and volatile oil of bitter almonds.

To form some notion of its properties, they digested almonds in ether till they were deprived of all their fixed oil. The residue dissolves almost completely in water, and gives a colourless, or slightly opalescent liquid. When heated to 158° it becomes muddy, and at 212° coagulates into a thick mass, having the aspect of starch mucilage. When amygdalin was added to the matter, no visible change took place, but a strong smell of hydrocyanic acid became perceptible; though no oil was deposited. Yet on distilling the mixture, a considerable quantity of the essential oil was obtained, and the emulsin was deposited in white flocks.

The solution of emulsin is precipitated by alcohol in thick white flocks. These flocks dissolve completely in water, even if they have been previously dried. And this solution produces the same effect with amygdalin as a solution of emulsin newly prepared.* This constitutes a remarkable difference between emulsin and vegetable albumen.

The investigation of emulsin was taken up by Mr Richardson, in the laboratory at Giessen, during the summer of 1837, and it was afterwards prosecuted by him in M. Pelouze's laboratory, in Paris, in the beginning of 1838. In these last experiments he was assisted by Dr R. D. Thomson of London.

The milk of sweet almonds was mixed with four times its volume of ether. The mixture was well agitated, and then left at rest for some days. A clear liquid gradually separated, upon which the ether, and a quantity of insoluble matter floated. The clear aqueous liquor being drawn off, was mixed with pure alcohol. An abundant

* Ann. de Chim. et de Phys. lxiv. 202.

white flocky precipitate fell, which was thoroughly washed, and then dried under the air pump, with sulphuric acid, for two or three weeks. In this state it was considered as pure uncoagulated emulsin. The coagulated emulsin was thrown down by boiling a portion of the aqueous solution of it.

When emulsin was boiled in barytes water, ammonia was evolved, and the emulsin gradually dissolved. The solution was treated with carbonic acid, to throw down all the uncombined barytes, and gently heated, to separate any bicarbonate of barytes that might have been formed. By evaporating the solution, a bitter tasted salt was obtained, which contained a large quantity of barytes. To the acid of this salt the name of *emulsic acid* has been given. Its characters and atomic weight have not yet been determined.

These facts render it exceedingly probable that emulsin is an amide of emulsic acid.

Mr Richardson made two analyses of it in Professor Liebig's laboratory, the mean of which gave

Carbon	48·835 or	24 atoms =	18	or per cent.	48·81
Hydrogen	7·732 or	23 atoms =	2·875	— —	7·79
Azote	18·911 or	4 atoms =	7	— —	18·99
Oxygen	24·722 or	9 atoms =	9	— —	24·41
			36·875		100

This formula can exhibit only the ratios between the atoms of each constituent. To know the true composition, it would be necessary to be acquainted with the atomic weight of emulsic acid. Were we to consider emulsic acid as C^{24} H^{21} Az^3 O^{10}, the constitution of emulsin might be represented thus, C^{24} H^{21} Az^3 O^9 + Az H^2; and the addition of an atom of water would convert it into an atom of emulsate of ammonia.

SECTION III.—OF MUCIN.

If we digest, or rather boil, alcohol upon the gluten of wheat, and filter the liquid while hot, it deposits on cooling a quantity of *mucin*. This substance possesses the following characters:—

1. It dries into transparent grains.
2. It burns like animal matter.
3. It is more soluble in water than gluten. And according to the analysis of Saussure, it constitutes about 4 per cent. of the gluten of wheat flour.
4. One hundred parts of hot water dissolve 4 parts of mucin. The solution runs very rapidly into putrefaction. Mucin is insoluble in ether.
5. The aqueous solution of mucin is precipitated by infusion of nutgalls, slightly by alcohol, and not at all by ammonia, lime water, acetate, or diacetate of lead, corrosive sublimate, or prussiate of potash.
6. When mixed with starch and made into a paste, and kept for 10 hours in a temperature of 145°, it converts the starch into sugar

and dextrine. Saussure's experiments were made upon the following proportions, with the following results:—

2 starch and 1 albumen formed 2 dextrine, with a trace of sugar.
2 starch and 1 gluten formed 6 dextrine, and 1·75 sugar.
2 starch and 1 mucin formed 22 sugar, and 15 dextrine.

SECTION IV.—OF GLUTIN.

This name has been given by M. de Saussure to the substance which had been already described by Einhoff, under the name of *kleber*. It may be obtained by boiling alcohol upon the gluten of wheat, and freeing the solution from mucin, by repeated precipitations. We obtain at last a transparent colourless solution. If the alcohol be evaporated, the glutin is left in the state of a yellowish translucent matter, which possesses the following properties:—

1. It is almost insoluble in water.
2. It is soluble in alcohol, both cold and hot.
3. It is soluble in dilute acids, especially the acetic.
4. It is soluble in caustic alkaline leys.
5. The acid solutions are precipitated by prussiate of potash—the inner surface of the glass vessel containing the solution being covered with a semitransparent coating.
6. It is precipitated by the infusion of nutgalls, and the precipitate is not redissolved by ebullition.

Glutin has been analyzed by Boussingault, who obtained

Carbon	53·75 or $8\frac{1}{2}$ atoms	= 6·375
Hydrogen	7·55 or 7 atoms	= 0·875
Azote	14·50 or 1 atom	= 1·750
Oxygen	24·20 or 3 atoms	= 3·000
	100*	12·000

Einhoff has shown that glutin exists also in rye and barley, though it is not easily obtained from them in a separate state.

M. de Saussure made some experiments in order to determine the alterations which wheat undergoes by germination. The following table exhibits the proportion of the several constituents, separated by analysis from 100 parts of wheat, before and after germination:—

	Wheat.	Do. after germination.	Do. after 6 months' steeping.
Starch . . .	72·72	65·80	61·81
Gluten . . .	11·75	7·64	0·81
Glutinous dextrine .	3·46	7·91	1·93
Glutinous sugar .	2·44	5·07	10·79
Albumen . .	1·43	2·67	8·14
Bran . . .	5·50	5·60	4·07
Carbonic acid . .	—	—	3·38
	97·30	94·69	90·93

* Ann. de Chim. et de Phys. lxiii. 229.

The third column exhibits the constituents of wheat that had been kept for six months under water, at a temperature between 72°·5, and 83°·75, and afterwards dried.*

No accurate experiments to determine the constituents of the four substances described in the preceding Sections have yet been made, with the exception of the analysis of glutin by Boussingault. M. Marcet subjected the gluten of wheat to an ultimate analysis, and obtained

Carbon	55·7
Hydrogen	7·8
Azote	14·5
Oxygen	22·0
	100·0†

And he says that the albumen of wheat yields the very same constituents in the same proportions.

These numbers lead to the following atomic constitution :—

9 atoms carbon	= 6·75	or per cent.	56·55
$7\frac{1}{2}$ atoms hydrogen	= 0·9375	— —	7·85
1 atom azote	= 1·75	— —	14·65
$2\frac{1}{2}$ atoms oxygen	= 2·50	— —	20·95
	11·9375		100

But as gluten of wheat is never free from starch, and as it is unlikely that the constitution of the albumen, mucin, and glutin should be exactly the same, little confidence can be put in Mr Marcet's analysis.

SECTION V.—OF ZEIN.

The name *zein* has been given, by Professor Gorham,‡ to the gluten of *zea mais*, or *Indian corn*.

It may be obtained by the following process :—

Treat the meal of mais with water, in the same way as wheat flour is treated to obtain the gluten of Beccaria. There will remain in the linen bag, in which the meal was washed, a matter insoluble in water. Digest this matter in alcohol ; mix the alcoholic solution with water, and distil off the alcohol. We obtain in this way a yellow, soft, flexible body, mixed with water. It possesses much viscosity and ductility ; but has neither taste nor smell. But water, most acids, and alkalies have little action on it.

Gorham assures us that it differs essentially from the gluten of wheat, by containing no azote ; and that it yields no ammonia when distilled. But Bizio affirms that he obtained ammonia by distilling the *zein*.

Its specific gravity, as determined by Bizio, is 1·0347. It swells up in cold alcohol, and when the liquid is boiled, a slimy solution takes place. Ether placed in contact with it acquires a fine yellow

* Memoires de la Societé Physique et d'Histoire Naturelle de Geneve, vi. 237.
† Ibid. iii. 217. ‡ Jour. of Science, xi. 205.

colour; but it does not dissolve it completely. Acetic acid dissolves it by the assistance of heat. Nitric acid converts it into a butyraceous mass, with the evolution of nitrous gas. This matter mixes with oils, and may be again separated by alcohol, in which it dissolves readily, and from which it may be obtained unaltered by evaporating the solution. Zein dissolves in concentrated sulphuric acid. The solution has a purplish-red colour, and is glutinous. Zein does not dissolve in muriatic acid, even at a boiling temperature.

SECTION VI.—OF VISCIN.

The characters of the substance called *viscin*, by Macaire, were first given by Vauquelin in 1799. It had collected on the epidermis of a species of *acacia*, brought to Europe by M. Micaut, and which Cels distinguished by the name of *Robinia Viscosa*.* Within these few years the same substance was observed exuding spontaneously from the involucrum of the *Atractylis gummifera*. He a second time determined its properties, gave it the name of *viscin*, and subjected it to a chemical analysis.†

But it was shown, in 1806, by M. Bouillon-Lagrange, that viscin is essentially the same with *bird-lime*.‡ Now, bird-lime was known to the ancients, being called ἰξὸς by the Greeks, and *viscum* by the Romans. Pliny informs us that it was made from *acini* (probably *ivy berries*), and he describes the process of the manufacture, and mentions the uses to which bird-lime was put.§

Viscin, when fresh, is soft and elastic, and has a greenish or brownish colour. It adheres firmly to the fingers, or to almost any body with which it comes in contact.

It is insoluble in water and fixed oils, slightly soluble in alcohol, and very soluble in ether and oil of turpentine. When heated it softens, melts, and swells, and becomes slightly yellow; when cooled it remains liquid, and attaches itself to the fingers like glue. It burns with a white flame, first becoming soft, and then melting. During its combustion it gives out much smoke, with the smell of empyreumatic oil. When distilled it gives off an acid, but no ammonia, showing that it contains no azote.

It is soluble in caustic potash, which becomes slightly coloured. Sulphuric acid dissolves it, assuming a deep brown colour. No artificial tannin is formed, but a great deal of charcoal is deposited. Nitric acid dissolves it by the assistance of heat. The solution is reddish-yellow. When evaporated to dryness a yellowish-white substance remains, not bitter, and containing no oxalic acid, but soluble in caustic potash, and burning like tinder.

Its constituents, as determined by the analysis of M. Macaire, are

* Ann. de Chim. xxviii. 233.

† Memoires de la Societé Physique et d'Histoire Naturelle de Geneve, vi. 27.

‡ Ann. de Chim. lvi. 24.

§ C. Plinii Secundi Hist. Mundi, lib. xvi. c. 44.

Carbon	75·6 or 13 atoms	= 9·75	or per cent.	75·0
Hydrogen	9·2 or 10 atoms	= 1·25	— —	9·6
Oyxgen	15·2 or 2 atoms	= 2·00	— —	15·4
	100·0*	13		100·0

But these proportions are so different from what have been found in other vegetable substances, that they must be confirmed by very careful experiments before we can rely upon them.

There can be little doubt that the viscid substance which covers the stem of the *lychnis viscaria*, *saxifraga tridactylites*, and a few other plants common in this country, is viscin; though, so far as I know, it has not yet been subjected to a chemical examination.

Artificial bird-lime is prepared from different substances in different countries. The berries of the misletoe are said to have been formerly employed. They were pounded, boiled in hot water, and the hot water poured off. At present bird-lime is usually prepared from the middle bark of the holly. The process followed in England, as described by Geoffroy, is as follows:—The bark is boiled in water seven or eight hours, till it becomes soft. It is then laid in quantities in the earth, covered with stones, and left to ferment or rot for a fortnight or three weeks. By this fermentation, it changes to a mucilaginous consistency. It is then taken from the pits, pounded in mortars to a paste, and well washed with river water. Bouillon-Lagrange informs us, that at Nogent le Rotrou, bird-lime is made by cutting the middle bark of the holly into small pieces, fermenting them in a cool place for a fortnight, and then boiling them in water, which is afterwards evaporated. At Commerci various other plants are used.†

Bouillon-Lagrange made bird-lime, for the purpose of analysis, by the following process:—He bruised a sufficient quantity of the middle bark of the holly, boiled it in water for four or five hours, and then deposited it in pits placed in earthen pans, where it continued, being moistened occasionally with water, till it became viscous. Lastly, it was freed from all heterogeneous substances, by washing it with pure water. Thus prepared, it resembled the bird-lime of Commerci very exactly.‡

Its colour is greenish, its flavour sour, and its consistence gluey, stringy, and tenacious. Its smell is similar to that of lintseed oil. When spread on a glass plate, and exposed to the air and light, it dries, becomes brown, loses its viscidity, and may be reduced to powder; but when water is added to it, the glutinous property returns. It reddens vegetable blues.

When gently heated it melts and swells, and emits an odour like that of animal oils. When heated on red-hot coals, it burns with a lively flame, and gives out a great deal of smoke, leaving a white ash composed of carbonate of lime, alumina, iron, sulphate, and muriate of potash.

* Jour. de Pharmacie, xx. 18. † Nicholson's Jour. xiii. 145.

‡ Bouillon-Lagrange, Nicholson's Jour. xiii. 145.

Water has little action on bird-lime. When boiled in water, the bird-lime becomes more liquid, but recovers its original properties when the water cools. The water, by this treatment, acquires the property of reddening vegetable blues, and when evaporated, leaves a mucilaginous substance, which may be likewise separated by alcohol.

A concentrated solution of potash forms with bird-lime a whitish magma, which becomes brown by evaporation, while ammonia separates. The compound thus formed is less viscid than bird-lime, and in smell and taste resembles soap. In alcohol and water it dissolves almost completely, and possesses properties similar to those of soap.

Weak acids soften bird-lime and partly dissolve it; strong acids act with more violence. Sulphuric acid renders it black; and when lime is added to the solution, acetic acid and ammonia separate. Nitric acid cold has little effect; but when assisted by heat, it dissolves the bird-lime; and the solution, when evaporated, leaves behind it a hard brittle mass. By treating this mass with nitric acid, a new solution may be obtained, which, by evaporation, yields malic and oxalic acids, and a yellow matter which possessed several of the properties of wax. Cold muriatic acid does not act on bird-lime; hot muriatic acid renders it black.

Bird-lime, when treated with chlorine, becomes white, and is divided into hard compact masses, having unaltered bird-lime in their centre. This white substance may be pulverized; it is insoluble in water, does not melt when heated; and when treated with nitric acid, it neither becomes yellow, nor does it yield resin.

Acetic acid softens bird-lime, and dissolves a certain portion of it. The liquid acquires a yellow colour. Its taste is insipid. When carbonate of potash is dropped into this solution, no precipitate falls. By evaporation it yields a resinous-like substance.

Some of the metallic oxides are reduced when heated with bird-lime. Litharge combines with it, and forms a kind of plaster.

Alcohol of the specific gravity 0·817 dissolves bird-lime at a boiling heat. On cooling it lets fall a yellow matter similar to wax. The filtered liquid is bitter, nauseous, and acid. Water precipitates a substance similar to resin.

Sulphuric ether dissolves bird-lime readily, and in great abundance. The solution is greenish. When mixed with water, an oily substance separates, which has some resemblance to lintseed oil. When evaporated, a greasy substance is obtained, having a yellow colour, and the softness of wax. Oil of turpentine dissolves bird-lime readily.

Such are the properties of artificial bird-lime, as far as they have been investigated by Bouillon-Lagrange.* It is obvious that it contained acetic acid, mucilage, and several alkaline and earthy bodies, which must be considered as foreign substances. When these are removed, the close analogy between artificial and natural bird-lime is sufficiently obvious.

* Nicholson's Jour. xiii. 146.

SECTION VII.—OF POLLENIN.

The term *pollenin* was applied by Dr John to a peculiar substance found in the pollen of the *pinus abies*, *pinus sylvestris*, *lycopodium clavatum*, and supposed by him to constitute the characteristic constituent of every species of pollen. It seems to have been first recognized in 1806, by Bucholz, in the pollen of the lycopodium.* From the experiments of Fourcroy and Vauquelin, it appears also to constitute a portion of the pollen of the *phœnix dactilifera*. John's analysis of the *pinus sylvestris*, in which he gives the characters of pollenin, as they had been previously given by Bucholz, may be found in the fourth volume of his *Chemical Researches*.

The easiest method of obtaining pollenin, is to digest the *lycopodium* of the shops in water, till every thing soluble in that mestruum be taken up. We must then digest it in the same way in alcohol, and, finally, in a weak solution of potash or soda. By this treatment, some sugar, extractive, and oil are removed, and 100 parts of lycopodium leave about 89·5 parts of pollenin. It preserves the yellow colour, the pulverulent form, and the great combustibility of lycopodium.

It is insoluble in water, alcohol, ether, fat and volatile oils, and likewise in naphtha.

If it be left moist in a humid situation, it soon putrefies, giving out a disagreeable odour, mixed with that of ammonia, and at last acquires exactly the smell of putrid cheese. Nitric acid acts on it as on gluten, converting it into oxalhydric and oxalic acid, bitter matter, and tallow.

According to Fourcroy and Vauquelin, the pollenin extracted from the date-tree dissolves slightly in muriatic acid, and the solution, which has a greenish-yellow colour, gives a precipitate of yellow pulverulent pollenin, when an alkali is poured into it.†

Braconnot examined the pollenin of the *typha latifolia*, and found its properties somewhat different. When freed by means of water, alcohol and ether, of every thing soluble in these liquids, its properties were the following:—When distilled it gave much less ammonia than vegetable albumen does. Concentrated sulphuric, muriatic, and acetic acids dissolve it without decomposition. Water throws it down from these solutions. The precipitate thus obtained is soluble in potash and ammonia, and the acids in their turn throw down the pollenin from the alkaline solutions. When the alkaline solutions are boiled, the pollenin is altered, for it is no longer precipitated by acids, though it is still capable of being thrown down by alcohol and infusion of nutgalls.‡

M. Macaire-Princep has examined the pollenin of the cedar. It is yellow, pulverulent, without taste or smell, and burns with less vivacity than the pollen of lycopodium. Besides pollenin, it contains resin, gum, sugar, and different salts, as, for example, malate and

* Gehlen's Jour. vi. 599. † Annales du Mus. d'Hist. Nat. i. 417.
‡ Ann. de Chim. et de Phys. xlii. 91.

sulphate of potash, phosphate of lime, and a little silica. He compares this pollenin with starch, and says that it is a mistake to suppose that pollenin contains azote.

The pollenin of the cedar is composed, according to his analysis, of

Carbon	40·0 or 11 atoms	= 8·25	or per cent.	39·76
Hydrogen	11·7 or 20 atoms	= 2·50	— —	12·05
Oxygen	48·3 or 10 atoms	= 10·00	— —	48·19
	100	20·75		100·00

The pollenin of lycopodium he found composed of

Carbon	50·2 or 17 atoms	= 12·75	or per cent.	51·12
Hydrogen	8·6 or 17½ atoms	= 2·1875	— —	8·79
Oxygen	39·2 or 10 atoms	= 10·00	— —	40·09
	98·0	24·9375		100·00

But these results being inconsistent with the previous observations of Vauquelin, Bucholz, and Braconnot, who observed the evolution of ammonia when pollenin was distilled, and therefore inferred the existence of azote as an essential constituent, would require to be repeated with much care, before they could be adopted.

M. Fritche has shown, by microscopical observations, that pollenin is in fact a complex organized body.* It is obvious from this, that it cannot with propriety be considered as an immediate vegetable principle.

SECTION VIII.—OF LEGUMIN.

The fleshy cotyledons of the seeds of all papilionaceous plants contain according to the experiments of Braconnot, a peculiar principle, to which he has given the name of *legumin*.† The investigation of these seeds was begun many years ago by Einhoff, who published an elaborate analysis of peas, beans, and kidney beans in 1805.‡ From peas Einhoff obtained a peculiar substance, to which he gave the name of animo-vegetable principle, and the properties of which he described. Braconnot's mode of obtaining legumin from peas was as follows:—

Ripe peas were macerated several days in warm water to render them soft, and cause them to swell. They were then reduced to a pulp in a marble mortar, mixed with pure water, and after being agitated, the whole was thrown upon a seirce. A milky liquid passed through, which being left for some time in a state of rest deposited the starch which it held in suspension. The muddy liquid remaining contains the legumin in solution, seemingly combined with a vegetable acid, and this matter gives it the property of frothing when agitated, like white of an egg when beat up with water. Yet it does not appear to contain any albumen, for when it is heated no flocky deposit takes place. But if we evaporate it, the legumin is deposited by little and little, under the form of diaphanous pellicles, having a

* Poggendorf's Annalen, xxxii. 481.

† Ann. de Chim. et de Phys. xxxiv. 69. ‡ Gehlen's Jour. vi. 115, 136, and 542.

mucilaginous appearance, and this deposition continues till the end of the evaporations.

Legumin thus obtained is still impure and has a greenish colour. If it be washed, while still moist, with boiling alcohol, the impurities are dissolved, and the legumin remains in a state of purity.

Thus obtained it has a fine white colour, and does not alter the colour of litmus paper. When dried it is semitransparent, and still retains its white colour. It is soluble in water, but insoluble in alcohol. Oxalic, malic, citric and other vegetable acids, even when diluted with a great deal of water, dissolve it with great readiness. The mineral acids on the contrary, precipitate it from its solutions, because it forms with them acidulous compounds, which are very little soluble. When the liquid is heated, these precipitates disappear, but on cooling, the whole is converted into a gelatinous mass, like pitch, which becomes again liquid when heated.

When heated with a little of any vegetable acid, tartaric acid, for example, it forms a thick mucilaginous liquid, which when diluted with water has scarcely any acid taste. Infusion of nutgalls throws down a copious white precipitate, which, when heated, contracts, and becomes buff-coloured. When legumin is long boiled with concentrated sulphuric acid, it is decomposed and produces the same substances as animal muscle does when treated in the same way. With nitric acid it behaves like vegetable albumen. Its solution in a vegetable acid is not precipitated by alcohol.

Alkaline hydrates and carbonates, even when very dilute, dissolve it with facility. It is soluble likewise in barytes and lime water, and the solutions froth like aqueous solutions of soap. When either of these two solutions is boiled, a coagulum is formed, and when an acid is added which forms an insoluble or little soluble salt with the lime or barytes (such as carbonic, sulphuric or phosphoric acid), there immediately precipitates a combination of legumin with the earthy salt.

With iodine it forms a soluble compound without the assistance of heat. But if we heat the liquid, a reddish-yellow precipitate falls, which preserves its colour after being dried. This precipitate is insoluble in water and alcohol, but dissolves readily in ammonia. The solution is colourless, but is precipitated yellow by acids. Starch gives a blue colour to this precipitate, and when it is heated above 212°, the iodine which it contains is volatilized, and the legumin remains behind.

Braconnot considers legumin as possessed of alkaline properties. It is in his opinion intermediate between gluten and vegetable albumen; differing from the former in being insoluble in alcohol, and from the latter in dissolving with facility in alkaline carbonates.

SECTION IX.—OF AMYGDALIN.

This name has been given by Dobereiner to a substance which exists in the bitter almond, though the sweet almond seems desti-

tute of it. Its properties were examined in detail by Robiquet and Boutron-Charlard.* And it was examined and analyzed by Wöhler and Liebig.†

The best mode of obtaining it, is to digest the matter of bitter almonds, deprived of their oil, in ether, and afterwards in hot anhydrous alcohol as long as there is any thing taken up. The first alcoholic decoction deposits on cooling a small quantity of amygdalin but the subsequent one deposits nothing. Mix all the alcoholic liquids and distil off the alcohol till the liquid is reduced to the consistence of a syrup. Put this syrup into a tall and narrow glass cylinder, and add 6 or 8 times its volume of ether, agitate well and leave the whole at rest. In a few hours the liquid divides itself into three layers; the uppermost, consisting of the ether containing in solution a little resin, is limpid and transparent; the middle layer, containing the amygdalin, seems as if it contained chalk; and the lowermost layer, containing an incrystallizable sugar, is limpid and amber-coloured. Remove by means of a syphon the uppermost and undermost layers. Dissolve the middle layer in boiling alcohol, and set the solution aside. The amygdalin is deposited in short white needles.

Wöhler and Liebig found the following process to yield the greatest quantity of amygdalin:—

The residue of bitter almonds, deprived of their fixed oil by expression, was treated twice successively by alcohol of 0·8157. The liquor was filtered through cloth, and the residue pressed out. On cooling the liquid becomes muddy and deposits a fixed oil which must be separated. It is then filtered in order to obtain it in a clear state. On being left for several days it deposits a quantity of amygdalin in crystals. Distil off the alcohol till the residue amounts only to $\frac{1}{6}$th of its original bulk. Let it cool and mix it with its own bulk of ether. The whole amygdalin precipitates. Collect it and subject it to pressure between folds of blotting paper, to get rid of a quantity of fixed oil with which it is mixed. Agitate it in ether to get rid of the last portions of this oil, then dissolve it in boiling alcohol. It crystallizes on cooling in white scales.

They have more lately ascertained that if the liquid containing the amygdalin be mixed with yeast, and fermented to get rid of the sugar contained in it, then filtered, evaporated to the consistence of a syrup and mixed with alcohol, the amygdalin is precipitated in the state of a white powder.‡

It has no smell. Its taste is at first sweet, then bitter, communicating the impression of bitter almonds. It cannot be sublimed. When heated it swells and is decomposed, giving out first the odour of caromel, and afterwards of hawthorn. It is not altered by exposure to the air. We do not know whether it be soluble in water. It is scarcely soluble in cold alcohol unless it contains water, but boiling alcohol dissolves it easily, and it crystallizes as the solution

* Ann. de Chim. et de Phys. xliv. 352, 376. † Ibid. lxiii. 185.

‡ Annalen der Pharmacie, xxiv. 45.

cools. It is insoluble in ether. Dry chlorine has no action on it; but the moist gas causes it to swell and changes it into a white powder insoluble in alcohol and in water. Nitric acid decomposes it, and among other products benzoic acid is formed. Caustic potash dissolves it; when the solution is boiled ammonia is disengaged, showing the presence of azote in amygdalin. The acids occasion no precipitate when added to the alkaline solution.

The crystals of amygdalin, according to the experiments of Wöhler and Liebig, are composed of

Amygdalin	89·43
Water	10·57
	100

This is obviously

1 atom amygdalin . . .	57
6 atoms water . . .	6·75
	63·75

It was analyzed by MM. Henry, junior, and Plisson, who obtained

Carbon	58·5616 or 38 atoms	= 28·50	or per cent.	58·61
Hydrogen	7·0857 or 27 atoms	= 3·375	— —	6·94
Azote	3·6288 or 1 atom	= 1·75	— —	3·60
Oxygen	30·7238 or 15 atoms	= 15·00	— —	30·85
	99·9999*	48·625		100·00

But it has been more lately analyzed with more accuracy by Wöhler and Liebig, who obtained

Carbon	52·00 or 40 atoms	= 30	or per cent.	52·62
Hydrogen	6·06 or 26 atoms	= 3·25	— —	5·70
Azote	3·069 or 1 atom	= 1·75	— —	3·07
Oxygen	38·871 or 22 atoms	= 22	— —	38·61
	100·000†	57		100

Comparing these numbers with the constitution of the crystals of amygdalin, it is obvious that its atomic weight is 57.

When amygdalin comes in contact with a substance in almonds, similar in its appearance to vegetable albumen, and which Wöhler and Liebig term *emulsin*, a decomposition immediately takes place, and hydrocyanic acid and oil of bitter almonds are immediately formed.

SECTION X.—OF GLAIRIN.

This name has been given to a peculiar substance which has been observed in the sulphureous mineral waters of the Pyrenees, particularly in those of Barege and Plombieres. It seems to have been first noticed by Vauquelin,‡ who described several of its properties and considered it as analogous to *gelatin*. M. Gimbernat noticed it in 1815 in the waters of Baden, and in 1818 in those of Ischia.

* Annalen der Pharmacie, p. 280. † Ibid p. 192.

‡ Ann. de Chim. xxxix. 173.

M. Anglada, professor at Montpellier, drew up an account of it in 1827, which was presented to the Royal Academy of Medicine of Paris, on which a report by M. Boudet was read at the meeting of that learned body on the 29th of December 1827.*

Glairin gelatinizes when the water containing it is sufficiently concentrated. Sometimes it is white, and at others of a red colour. When dried it shrinks to $\frac{1}{60}$th of its bulk while moist. It has not the property of gluing substances together, like gelatin and albumen. It saturates ammonia, decomposes several metallic salts, and acquires different colours when acted on by different reagents. It is destitute of taste and smell.

When decomposed it yields ammonia, showing that azote is one of its constituents. It is capable also of putrefaction like animal bodies. The general opinion entertained is, that it is of vegetable origin, and allied to the genus tremella, though nobody has been able to account for its existence in mineral waters. It is the opinion of some, that the sulphuretted hydrdogen which exists in mineral waters owes its origin to the decomposing action of glairin upon sulphates originally contained in these waters.

CHAPTER VIII.

OF CAOUTCHOUC.

About the beginning of the 18th century, a substance called *caoutchouc* was brought as a curiosity from America. It was soft, wonderfully elastic, and very combustible. The pieces of it that came to Europe were usually in the shape of bottles, birds, &c. This substance is very much used in rubbing out the marks made upon paper by a black-lead pencil; and therefore in this country it is often called *Indian-rubber*. Nothing was known of its production, except that it was obtained from a tree, till the French academicians went to South America in 1735, to measure a degree of the meridian. M. de la Condamine sent an account of it to the French Academy in the year 1736. He told them that there grew in the province of Esmeraldas, in Brazil, a tree called by the natives *Hhevé;* that from this tree there flowed a milky juice, which, when inspissated, was *caoutchouc*. Don Pedro Maldonado, who accompanied the French academicians, found the same tree on the banks of the Maragnon; but he died soon after, and his papers were never published. Mr Fresnau, after a very laborious search, discovered the same tree in Cayenne. His account of it was read to the French Academy in 1751.†

It is now known that there are at least two trees in South America from which caoutchouc may be obtained; the *hævea caoutchouc*, and

* Jour. de Pharmacie, xiv. 76. † Mem. Par. 1751, p. 319.

the *jatropha elastica;* and it is exceedingly probable that it is extracted also from other species of *hævea* and *jatropha.* Several trees likewise which grow in the East Indies yield caoutchouc; the principal of these are, the *ficus indica*, the *artocarpus integrifolia*, and the *urceola elastica;* a plant discovered by Mr Howison, and first described and named by Dr Roxburgh.* Dr Benjamin Smith Barton is said to have obtained it from the juice of the *smilax caduca*, which grows abundantly in the neighbourhood of Philadelphia.† Mr Woodcock found it in the milky juice of the *asclepias vincetoxicum.*‡ It is said also to be furnished by the *castilleja elastica*, *cecropia peltata*, *hippomene biglandulosa*, and *ficus religiosa.* Even the *papaver* and *lactuca* are said to yield it. Probably more than one species of caoutchouc exists; but this has not yet been established by experiment. Great quantities of it are now imported into this country both from South America and the East Indies, being employed in the manufacture of Mr Macintosh's water-proof cloth.

When any of these plants is punctured, there exudes from it a milky juice, which, when exposed to the air, gradually lets fall a concrete substance, which is caoutchouc.

I have received, more than once, bottles filled with the liquid as it flows from the trees in South America. But though the bottles were nearly full, and had been carefully closed to exclude all communication of common air, the caoutchouc had been all deposited during the passage, and had moulded itself into the shape of the bottle. Not the smallest trace of caoutchouc, could be detected in the liquid still remaining in the bottle. Mr Faraday seems to have been more fortunate. The juice as he received it was pale yellow, thick, and similar to cream. It was covered in the bottle containing it with a coating of caoutchouc, amounting to about $\frac{1}{5}$th per cent. of the weight of the liquid.§ Its odour is sourish and a little putrid. Its specific gravity was 1·01174. When spread in thin layers on a solid body it becomes quickly solid, and is coverted into common caoutchouc.

Caoutchouc was no sooner known than it drew the attention of philosophers. Its singular properties promised that it would be exceedingly useful in the arts, provided any method could be fallen upon to mould it into the various instruments for which it seemed particularly adapted. Messrs de la Condamine and Fresnau had mentioned some of its properties; but Maquer was the first person who undertook to examine it with attention. His experiments were published in the *Memoirs of the French Academy* for the year 1768. They threw a good deal of light on the subject; but Maquer fell into some mistakes, which were pointed out by Mr Berniard, who published an admirable paper on caoutchouc in the 17th volume of the

* Asiatic Researches, v. 167. London Edition.

† Phil. Mag. xl. 66. ‡ Ibid. 125.

§ The caoutchouc deposited in the bottles which I received amounted to above 40 per cent. of the whole fluid.

Journal de Physique. To this paper we are indebted for the greater number of facts at present known respecting caoutchouc. Mr Grossart and Mr Fourcroy have likewise added considerably to our knowledge of this singular substance; both of their treatises have been published in the 11th volume of the *Annales de Chimie.* The latest set of experiments on it was made by Mr Faraday, and we are indebted to Dr Dalton for an analysis of the volatile oil into which it is converted by distillation.*

Caoutchouc when pure has a pale yellow colour, and is destitute both of taste and smell. The blackish colour of the caoutchouc of commerce is owing to the method employed in drying it after it has been spread upon moulds. The usual way is to spread a thin coat of the milky juice upon the mould, and then to dry it by exposing it to smoke; afterwards another coat is spread on, which is dried in the same way. Thus the caoutchouc of commerce consists of numerous layers of pure caoutchouc, alternating with as many layers of soot. What comes from the East Indies is in yellow cakes or pieces, having obviously been allowed to inspissate, by exposing the juice containing it to the air.

Caoutchouc at the temperature of 32°, is hard, and possesses but little elasticity; but when heated up to 60° or 70°, it becomes soft and pliable like leather. It is exceedingly elastic and adhesive; so that it may be forcibly stretched out much beyond its usual length, and instantly recovers its former bulk when the force is withdrawn. It cannot be broken without very considerable force. Its specific gravity is 0·9335.†

To the late acute philosopher, Mr Gough of Kendal, I was indebted for some very important experiments on the connection between the temperature of caoutchouc and its elasticity. They have been since published in the second volume of the *Manchester Memoirs*, second series. It is necessary to premise, that Mr Gough had been blind from an infant, and that therefore his sense of touch was peculiarly delicate; so much so, that he was an excellent botanist, and could distinguish plants with the utmost certainty by the feel; a power so extraordinary, that we who enjoy the advantage of sight can scarcely conceive how it can be acquired. Mr Gough's experiments are as follows:—

Take a thong of this substance two or three inches long, and a few lines in breadth and thickness; put it in warm water till it becomes quite pliant: then, holding it merely extended between the two hands, bring the edge of it in contact with the lips, and observe the temperature (of the variations of which, that part of the face is a very nice judge); then remove the thong a few lines from the lips, and stretch it forcibly, and bring it again in contact with the lips, and a very sensible increase of temperature will be perceived. Allow it to relax to its former state, and the temperature will be perceived immediately to sink. If we stretch the thong again, and then plunge

* Phil. Magazine (Third Series), ix. 479. † Brisson.

it immediately into cold water, keeping it extended for a minute or more in the liquid, on letting go one end it will be found to have lost much of its contractile power; for it will not return to its former dimensions. But if we plunge it into warm water, or warm it by holding it for some time in the shut hand, it will begin to contract again, and soon return to its former figure and size. These experiments are of great importance, as they furnish a very palpable and convincing proof that ductility is owing to latent heat as well as fluidity. They afford a fine illustration of Dr Black's theory of latent heat. We see clearly that the elasticity of caoutchouc and the ductility of metals are different cases of one and the same thing.

Caoutchouc is not altered by exposure to the air; it is perfectly insoluble in water: but if boiled for some time its edges become somewhat transparent, owing undoubtedly to the water carrying off the soot; and so soft, that when two of them are pressed and kept together for some time, they adhere as closely as if they formed one piece. By this contrivance pieces of caoutchouc may be soldered together, and thus made to assume whatever shape we please.*

When caoutchouc has once become solid, it cannot be dissolved in water, alcohol, acids, or alkalies. By long boiling in water it softens and swells up, and while in that state it is acted on with greater facility by different menstrua, but when exposed to the air, it soon resumes its former state. By this treatment, the black South American caoutchouc becomes translucent on the edges, obviously by the removal of the soot.

Caoutchouc is soluble in ether. This property was first pointed out by Macquer. Berniard, on the contrary, found that caoutchouc was scarcely soluble at all in sulphuric ether, which was the ether used by Macquer, and that even nitric ether was but an imperfect solvent. The difference in the results of these two chemists was very singular; both were remarkable for their accuracy, and both were too well acquainted with the subject to be easily misled. The matter was first cleared up by Mr Cavallo. He found that ether, when newly prepared, seldom or never dissolved caoutchouc completely; but if the precaution was taken to wash the ether previously in water, it afterwards dissolved caoutchouc with facility. Mr Grossart tried this experiment, and found it accurate.† It is evident from this that these chemists had employed ether in different states. The washing of ether has two effects. It deprives it of a little alcohol with which it is often impregnated, and it adds to it about $\frac{1}{10}$th of water, which remains combined with it. Alcohol precipitates the caoutchouc from this solution.

When the ether is evaporated, the caoutchouc is obtained unaltered. Caoutchouc, therefore, dissolved in ether, may be employed to make instruments of different kinds, just as the milky juice of the *hævea;* but this method would be a great deal too expensive for common use.

* Grossart, Ann. de Chim. xi. 153. See a method of making caoutchouc tubes by means of this property, Phil. Mag. xxii. 340.

† Grossart, Ann. de Chim. xi. 147.

Caoutchouc is soluble in volatile oils;* but, in general, when these oils are evaporated, it remains somewhat glutinous, and therefore is scarcely proper for those uses to which, before its solution, it was so admirably adapted. Coal naphtha was found by Mr Macintosh, capable of dissolving caoutchouc by the assistance of a long-continued heat. It is this solution, spread in numerous coats between two folds of cloth, that renders the cloth water-tight. The quantity of naphtha required for this solution is now so great, that enough of it cannot be procured for the purpose, notwithstanding the numerous coal-gas works scattered over Great Britain. Great quantities of oil of turpentine are also employed; for it has been long known that oil of turpentine and coal naphtha, are almost identical in their properties.

Caoutchouc dissolves both in the fixed and volatile oils; but when the solutions are dried, the caoutchouc remains in an adhesive state and destitute of elasticity. According to Achard, it is not soluble in oils of lavender, cloves, cinnamon, nor lintseed, nor in Dippel's animal oil. But this statement is not likely to be correct. Lampadius found that when put into 4 times its weight of bisulphuret of carbon, it becomes soft. If in this state we put it into 16 parts of new bisulphuret of carbon, and stir the whole frequently, we obtain in a few days a milky liquor, which leaves the caoutchouc, when evaporated, in its original elastic state.

It is said by Berniard to be insoluble in alkalies; but I find upon trial that this is a mistake. I was led to make the experiment by an accident. I employed a caoutchouc bottle fitted with a stop-cock in the usual way for holding ammoniacal gas. The gas very soon disappeared, though the bottle was perfectly air-tight, as I learned by plunging it in water. This induced me to fill it repeatedly with gas. In a short time it became evident that the gas had been absorbed by the bottle itself. It became soft and then glutinous, and never recovered its elasticity. I than tried the alkalies in general, and found that they were all capable of producing the same changes on caoutchouc, and even of dissolving it, though in a very minute proportion.

The acids act but feebly upon caoutchouc. Sulphuric acid, even after a very long digestion, only chars it superficially. The proportion of charcoal obtained in Mr Hatchett's experiments was only 12 per cent. and he could observe no traces of artificial tannin.† But when heat is applied the caoutchouc is completely decomposed. When treated with nitric acid, there came over azotic gas, carbonic acid gas, prussic acid gas; and oxalic acid is said to be formed.‡ Muriatic acid does not affect it.§ The other acids have not been tried.

When heated to a temperature of about 248°, it melts, and on cooling, remains in a semifluid adhesive state, somewhat like tar, or

* Berniard.

† Third Series of Experiments on Artificial Tannin, Phil. Trans. 1806.

‡ Ann. de Chim. xi. 232. § Berniard.

rather turpentine. In this state, in close vessels, it remains unaltered for years, but when spread in thin layers and exposed to the air, it gradually, but very slowly acquires hardness. After fusion, it still continues insoluble in alcohol of 0·815, or nearly so. It is equally little soluble in the caustic alkalies.

When caoutchouc is heated sufficiently in the open air, it smokes, giving out an odour which is not disagreeable, it then catches fire and burns with a strong yellow flame, giving out much smoke. It was ascertained some years ago, by Messrs Beale and Enderby of London, that when caoutchouc is distilled in close vessels, it furnishes $83\frac{1}{3}$ per cent. of volatile oil. There passes off at the same time, a quantity of combustible gas, but neither carbonic acid, water, nor ammonia. This seems to show that caoutchouc contains neither oxygen nor azote.

The oil has at first a dark colour, but when repeatedly rectified it becomes limpid and colourless, and has a specific gravity of only 0·640. It begins to boil at 95°, but during the boiling it rises as high as 149°. It is obvious from this that it is not homogeneous. Its boiling point, as determined by Dr Dalton, is 108°. And the elasticity of its vapour, is nearly the same as that of ether at the same temperature. It evaporates rapidly, and the evaporation is attended with the evolution of a good deal of cold. Dr Dalton found that its vapour was not absorbed by water. Of course air or oxygen gas impregnated with it over water, acquired a certain augmentation of bulk according to the temperature, which augmentation of bulk was permanent.

Dr Dalton took the specific gravity of this vapour, and found it 2·00. He found that when this vapour was mixed with oxygen gas, in the requisite proportions, it detonated by the electric spark, and was converted into carbonic acid gas and water. 1 volume of the vapour requires for complete combustion, 6 volumes of oxygen gas. The product is 4 volumes of carbonic acid gas and water, and nothing else. It is clear that 4 volumes of the oxygen gas, went to the formation of carbonic acid, and 2 volumes to the formation of water, which would require 4 volumes of hydrogen gas. Hence this vapour is composed of 4 volumes carbon vapour, and 4 volumes hydrogen gas united together, and condensed into one volume.

4 volumes carbon weigh .	1·6666
4 volumes hydrogen gas .	0·2777
	1·9444

Hence the true specific gravity is 1·9444, and it is a *tetarto-carbo-hydrogen;* or the same as 2 volumes of olefiant gas condensed into 1 volume.

The oil in the liquid state must be a compound of

Carbon	85·71
Hydrogen	14·29
	100·00

According to Mr Faraday's analysis, the liquid from which caoutchouc is deposited, is composed of

Water*	56·37
Caoutchouc	31·70
Albumen	1·90
Wax, a trace . . .	—
An azotic body† . . .	7·13
Gummy body . . .	2·90
	100·00

Mr Faraday also analyzed caoutchouc, and found it composed of

Carbon	87·2 or 8 atoms = 6	or per cent.	87·27
Hydrogen	12·8 or 7 atoms = 0·875	— —	12·73
	100·0	6·875	100·00

The probability is, that it is composed of an equal number of atoms of carbon and hydrogen. If we were to consider the volatile oil obtained by distilling the caoutchouc, as exhibiting its constitution correctly, it would consist of

4 atoms carbon . . .	= 3·0
4 atoms hydrogen . . .	= 0·5
	3·5

This would give the constitution, per cent.

Carbon	85·72
Hydrogen	14·28
	100·00

Dr Gregory found that when this oil was mixed with sulphuric acid in small quantities at a time, cooling it after each addition, and corking the tube in which the mixture was made, we obtain a liquid swimming over a brown matter, and amounting to about half the oil employed. This liquid being washed with water and potash, furnishes an oil having an aromatic smell, and boiling at 437°, or a little higher. This new oil is composed of the same number of atoms of carbon and hydrogen. Liebig conjectured it to be eupion, but Dr Gregory does not think this likely.‡

Caoutchouc has of late years, in London, been rolled out into thin sheets, which are exceedingly useful in the laboratory, for joining glass tubes together, so as to make the joint air-tight, and at the same time preserve its flexibility. Bottles of it, or rather balloons, blown thin by steeping the American little bottles of it in ether containing alcohol, and blowing them out to the requisite size, are convenient for holding small quantities of gas without altera-

* The water held in solution a little free acid, which precipitated nitrate of lead, and gave a green colour to the persalts of iron, without occasioning any precipitate.

† This substance had a bitter taste, and was soluble, with a brown colour, in water and alcohol.

‡ Jour. de Pharmacie, xxii. 382.

tion. The quantity consumed in this country, in the manufacture of water-proof cloth, is very great indeed. In those countries where it is indigenous, it is applied to a vast variety of uses; shoes, boots, cloaks, &c., are made of it, which, from being impervious to water, are found extremely convenient under a great variety of circumstances.

A set of experiments on the products of the distillation of caoutchouc, has lately been made by M. Bouchardat.* By distilling at a low temperature, and exposing the products to the action of a freezing mixture surrounding the receivers, he obtained five different liquids.

1. *Eupion.* A colourless limpid liquid, of the specific gravity 0·69. It boils at 124°, is insoluble in water, but soluble in all proportions in absolute alcohol, and is not acted on by acids or alkalies.

2. *Tetarto-carbo-hydrogen*, or the *carburet of hydrogen* of Faraday.

3. *Caoutchene.* This is an oily substance, which is distilled over by subjecting the product of the distillation of caoutchuc to a temperature between 50° and 64°. This substance, when exposed to a freezing mixture, crystallizes in long needles. When obtained by compression, it constitutes a white opaque mass. It melts at 14° into a transparent liquid, which boils at 58°, and has a specific gravity of 0·65. It is insoluble in water, but very soluble in absolute alcohol and in ether. Alkaline solutions do not act upon it. Sulphuric acid acts upon it as upon tetarto-carbo-hydrogen. According to Bouchardat, it is composed of

Carbon	85·65
Hydrogen	14·18
	99·83†

This is obviously 1 atom carbon, and 1 atom hydrogen. It is, therefore, one of the numerous tribe of carbo-hydrogen. How many atoms of each constituent it contains we do not know, as the specific gravity of the vapour of caoutchene has not been determined.

4. *Heveëne.* This is an oily body, which remains after the volatile oils are distilled off along with water. It is a transparent liquid, having a light amber colour, an empyreumatic smell, and an oleaginous consistence. Its taste is acrid, and it boils at 600°. It does not become solid, though exposed to the most powerful refrigerents. Its specific gravity is 0·921. It burns like the volatile oils, giving out much smoke. It is soluble in all proportions in alcohol and

* Jour. de Pharmacie, xxiii. 454.

† These numbers do not agree with his own data, according to which the composition should be

Carbon	94·04
Hydrogen	14·75
	108·79

There is doubtless a typographical error in some of the figures.

ether, and in the fixed and volatile oils. It neither acts as an acid nor alkali. Its constituents were found to be

Carbon	86·22
Hydrogen	13·99
	100·21

obviously another of the carbo-hydrogen tribe, already so numerous.

It absorbs chlorine, thickens, and gives out muriatic acid. In the same way it combines with bromine and iodine. It thickens also when acted on by alkalies, and absorbs oxygen.

Sulphuric acid darkens the colour. If the mixture be left for some days, a colourless liquid swims upon the surface, which possesses the characters of eupion.

The fifth product has not been described.

CHAPTER IX.

OF EXTRACTIVE.

The term *extract* (*extractum*) was employed by apothecaries to denote that portion of any vegetable substance which had been dissolved by digesting it in any menstruum whatever, and which had afterwards been reduced to a thick consistence, by distilling off the menstruum, if valuable, or by evaporating it away, if not worth preserving. So that originally, the portions of plants dissolved by water, alcohol, wine, acetic acid, carbonate of potash, &c., and afterwards inspissated, were called *extracts*. This is the meaning which the word bears in the *Pharmacopée Royale Galenique et Chymique of Charas*, published at Paris in 1676.* Thus the *extract of opium* of Charas was made by digesting opium first in water, and afterwards in alcohol, till every thing soluble in these menstrua had been taken up. The two solutions were mixed, the alcohol distilled off, and the water evaporated in a gentle heat. What remained was called *extract of opium*. In process of time, these *extracts* were divided into two sets; namely, *watery and spirituous*, or *gummy and resinous*, according as the menstruum employed was water or alcohol. This distinction was attended to in the time of Neumann.† Afterwards the term *extract* came to be restricted to what was obtained from vegetables, by macerating them in water, and evaporating the watery liquid to dryness.

The extracts obtained in this way were generally considered as *soaps*, till Fourcroy and Vauquelin published some observations on the subject in 1790.‡ According to them, *extract* is a substance at first soluble in water; but which, when the solution is exposed to the air, absorbs oxygen, and becomes insoluble. Chlorine gas

* See page 721. † See Neumann's Chemistry, p. 268.
‡ Ann. de Chim. vi. 180.

speedily converts it into a solid yellow substance insoluble in water, but soluble in alcohol and alkalies. They inform us that they examined 12 different extracts, and found the same characters in all.

In the year 1791 they published an elaborate analysis of the Cinchona bark of St Domingo, in which a great many experiments on *extract* are stated.* And soon after, Vauquelin made a set of experiments on the extractive principle of vegetables.† Fourcroy, in his *General System of Chemical Knowledge*, published about the beginning of the present century, recapitulates the facts ascertained previously by Vauquelin and himself. The *extracts* from vegetables are very complex in their nature ; but they all, in his opinion, contain a peculiar principle, to which he confined the term *extract*. According to him, it possesses the following properties :—

It is at first soluble in water, but rapidly absorbs oxygen from the air, or other substances capable of yielding it. By this absorption, it acquires a brown colour, and becomes insoluble in water. It has a strong affinity for alumina, and is taken away, and the liquid discoloured, when alum, mixed with an alkali, is agitated in a solution containing extract.

Fourcroy was of opinion that extract was not perfectly identical, but possessed different characters, according to the plant from which it was extracted, though every species of *extract* possessed the properties above stated. His notions on the subject, however, were too crude and unsatisfactory to merit a lengthened detail.

Saussure afterwards showed that the substance called *extract* or *extractive*, by Fourcroy and Vauquelin, did not combine with the oxygen which was absorbed, but gave out hydrogen to it, so as to convert it into water. The extractive, therefore, was not rendered insoluble by uniting with oxygen, but by being deprived of hydrogen. It contains a greater proportion of carbon than it did when soluble in water, and hence doubtless the reason why it assumes a brown colour.

Berzelius has distinguished this brown extractive by the name of *apotheme* (by which he means *deposite*).‡ It possesses the following properties.

It is not completely insoluble in water, communicating a yellow, reddish-brown, or red colour to that liquid, and is again deposited when the liquid is evaporated. But it is dissolved with very great difficulty, and a minute portion of it communicates a good deal of colour to that liquid. Boiling water dissolves more than cold, and the excess is deposited as the solution cools. It is much more soluble in alcohol than in water, and more soluble in hot than in cold alcohol.

Its best solvent is caustic potash, which dissolves a great quantity of it, and assumes a deep brown colour. The alkaline carbonates dissolve it also. The acids throw it down from these solutions.

The apotheme thus set at liberty, combines with the excess of

* Ann. de Chim. viii. 113. † Jour. de la Societ. des Pharm. iv. 133.
‡ Traité de Chimie, v. 548.

acid employed to throw it down, and acquires the property of reddening litmus paper. It has a strong tendency to combine with acid bodies. This doubtless alters its characters. But it is very probable that there are various species of apotheme, differing from each other according to the plants from which they have been obtained, though this subject has not hitherto drawn the attention of modern chemists. We want a set of experiments on this subject, with an ultimate analysis of apotheme in as pure a state as possible, and extracted from different plants.

It would be useless to give an account of the different extracts prepared by apothecaries for medicinal uses. They all contain a great variety of substances, and even the nature of their ingredients varies according to the methods employed to prepare them. When extracts are inspissated, *in vacuo*, at a low temperature, they all redden vegetable blues, and in general contain uncombined phosphoric acid.

CHAPTER X.

OF BITTER PRINCIPLES.

Many vegetable substances have an intensely bitter taste, and on that account are employed in medicine, by brewers, &c. This is the case with the wood of the *quassia amara* and *excelsa*, the common *quassia* of the shops; with the roots of the *gentiana lutea*, common *gentian;* the leaves of the *humulus lupulus*, or *hop;* the bark and wood of the *spartium scoparium*, or common broom; the flowers and leaves of the *anthemis nobilis*, or *chamomile;* and many other substances. From the most recent examination of these plants by chemists, there seems reason to conclude that these bitter tasted substances differ somewhat in their characters, according to the plant from which they are extracted. There does not, then, exist a single bitter principle which stamps its characters on all the plants which contain it, but a great variety of bitter principles which have hitherto been very imperfectly investigated.

It appears, from the experiments of Hoff, that when the bitter infusions of various plants are digested with charcoal, in a temperature between 77° and 86°, they lose their bitter taste, either entirely or partially. This was the case with the infusion of arnica, of the rinds of bitter oranges, calamus, carduus benedictus, chamomile, chicory, fumetary, saponaria, tansey. Gentian, quassia, menyanthus, and lichen islandicus were very little altered by this treatment. Animal charcoal was found to act still more powerfully than vegetable.*

The following are some of the most remarkable bitter substances hitherto examined:—

* Jour. de Pharmacie, xvii. 172.

1. *Quassite.* This name has been given by Wiggers to the bitter principle of the *quassia amara* and *excelsa*.* He procured it by the following process:—

The sliced wood was boiled in water, and the filtered decoction was evaporated to $\frac{1}{4}$th of its bulk. After cooling, it was mixed with a quantity of dissolved lime; and the mixture was frequently agitated for 24 hours. Pectin, and some other substances, were separated by the lime. The filtered solution was now evaporated to dryness, and the residue treated with alcohol of specific gravity 0·831. The quassite was dissolved, together with some common salt, saltpetre, and a brown colouring matter. When the alcohol was distilled off, and the residue evaporated to dryness, a light-yellow crystalline matter remained, which was dissolved in as small a quantity of absolute alcohol as possible, and mixed with a little ether. This solution was filtered and evaporated. These solutions and evaporations were repeated till the quassite was obtained pure.

Quassite thus obtained, possesses the following properties:—It is crystallized in very small white prisms. But, for the formation of these prisms, the presence of water is necessary. Its taste is intensely bitter. It has no smell, and is not altered by exposure to the atmosphere. 100 parts of cold water dissolve only 0·45 of quassite. But the solubility is increased by several salts and vegetable principles. This solution is precipitated white by tannin, but not by iodine, chlorine, corrosive sublimate, salts of iron, acetate, or subacetate of lead. It is very little soluble in ether. The best menstruum is alcohol, which acts more powerfully, the stronger and the hotter it is. Hence a saturated solution of quassite in absolute alcohol becomes muddy when a little water is added, and the quassite may be redissolved, by adding to the alcohol a sufficient quantity of water. The alcoholic solution is not thrown down by acetate or subacetate of lead; but it is by corrosive sublimate. All its solutions are colourless. It is a neutral body. Sulphuric and nitric acids dissolve it, but do not lose their acid qualities; and the nitric acid of the specific gravity 1·230, may be driven off by heat, leaving the quassite unaltered. When heated it melts like a resin, and its point of fusion is only a little higher than that of common rosin. On cooling it forms a translucent yellowish mass, which is very brittle. When heated to 212° in a dry atmosphere, it loses about 1·3 per cent of its weight; and when fused, the loss amounts to 1·76 per cent. When more strongly heated it becomes brown, and is charred.

Quassite, according to the analysis of Wiggers, is composed of

Carbon	65·75 or	10 atoms =	7·5	or per cent.	66·66
Hydrogen	6·89 or	6 atoms =	0·75	— —	6·66
Oxygen	27·36 or	3 atoms =	3·0	— —	26·66
	100·00		11·25		100·00

* Annalen der Pharmacie, xxi. 40.

2. *Gentianite.* This substance, from the *gentiana lutea*, has been very imperfectly examined by M. Leconte.* The alcoholic extract of the root contains it in the state of greatest purity. When this extract is treated with water, an excessively bitter solution is obtained, which reddens litmus paper. Subacetate of lead throws down the acid. A current of sulphuretted hydrogen throws down the lead from the liquid, and leaves an extract very bitter and sweet, which is very soluble in water. Ether dissolves from it a fatty matter, or oil, resin, and wax. The bitter principle and sugar still remain, and have not been separated from each other. From the latter experiments of Trommsdorf, it appears that the crystallized substances from the root of gentian, obtained by Henry and Caventou in 1821, but first purified by Trommsdorf, is tasteless, has a sulphur-yellow colour, is insoluble in cold, and but slightly soluble in hot water, but soluble in alcohol and ether. It may be sublimed in yellow needles. It seems to be a neutral substance, and cannot be the body to which gentian owes its bitterness.†

3. *Cytisite.* This substance was obtained by Chevalier and Lassaigne, in 1818, from the seeds of the *cytisus laburnum*.‡ The process followed was the following:—

The alcoholic extract of the seeds was treated, and the solution precipitated, by acetate of lead. A current of sulphuretted hydrogen gas was passed through the filtered liquid. It was filtered again and evaporated.

It is a greenish-yellow bitter-tasted substance, readily soluble in water and alcohol, and precipitated by diacetate of lead and nitrate of silver. When taken internally to the extent of 8 grains, it was found to act with great violence, producing vertigo and violent spasms, quickening the pulse, and occasioning vomiting. These symptoms lasted about two hours, and left a prostration of strength, which continued a long time. It is, doubtless, to the cytisin that the berries of the *cytisus laburnum* owe their poisonous qualities.

4. *Bryonite.* This substance was discovered, in 1807, by Vauquelin, in the root of *bryonia alba*, as *white bryony*.§

It was extracted by Brandes and Firnhaber, by the following process:—‖

The filtered juice was raised to the boiling temperature, and filtered again. It was now mixed with diacetate of lead. The precipitate was washed and decomposed by sulphuretted hydrogen. The solution thus obtained was evaporated to dryness, and the dry residue being digested in alcohol, the bryonite was dissolved.

The process of Dulong¶ was the following:—The expressed juice of the root was mixed with water, and left at rest. Starch was deposited, which was separated, and washed with a little water. The filtered liquid being raised to the boiling temperature, the albumen coagulated, and was separated by the filter. The liquid

* Jour. de Pharmacie, xxiii. 476. † Ann. der Pharmacie, xxi. 134.
‡ Jour. de Pharmacie, iv. 340. § Ann. de Mus. d'Hist. Nat. viii. 88.
‖ Br. Arch. iii. 351. ¶ Jour. de Pharmacie, xii. 158, 325, 507.

was now evaporated to the consistence of an extract. This extract was digested in hot alcohol till every thing soluble was taken up. The alcoholic solution was distilled, and the residue treated with water, which left a little resin undissolved. The aqueous solution being gently evaporated, the bryonite remained in a state of purity.

Bryonite thus obtained, is a yellowish-brown extractive-looking substance, having an exceedingly bitter taste. It is soluble in water. Alcohol dissolves it better when it contains water, than when anhydrous. In ether it is insoluble. It contains azote, and when distilled furnishes ammonia. It possesses neither acid nor alkaline properties, and cannot be obtained in crystals. Chlorine does not act upon it. Concentrated sulphuric acid dissolves it, assuming at first a blue colour, and then a green, so deep, that it is difficult to distinguish it from black. Nitric acid dissolves it, forming a liquid, at first brown, but becoming speedily yellow, from which water throws down a light yellow precipitate. If we heat the solution, nitrous gas is given out; and when we evaporate to dryness a yellow resin remains. Muriatic acid dissolves it with nearly similar phenomena.

The caustic alkalies dissolve bryonite without altering it. Its solution in water is not precipitated by acetate or nitrate of lead, protochloride of tin, tartar emetic, nor by the salts of zinc, iron, or copper. But it is precipitated white by nitrate of silver, yellow by chloride of gold, and in great abundance by nitrate of mercury and subacetate of lead. The infusion of nutgalls throws down a copious grey precipitate, difficultly soluble in water; but more easily in alcohol

5. *Centaurite.* This name may be given to the bitter substance which exists in the leaves of the *centaurea benedicta*, or *blessed thistle.* It was extracted by M. Morin, in the following way:—*

When the dried leaves are digested in alcohol, that liquid dissolves a green resin mixed with a fat oil, a brown resin, the peculiar bitter principle to which the centauria owes its qualities, extractive, sugar, and nitre.

The alcoholic extract, when treated with ether, gives out the green resin, the fat oil, and the bitter principle. When the portion insoluble in ether is treated with water, the brown resin remains undissolved. When acetate of lead is dropt into the aqueous solution, a precipitate of malate and phosphate of lead falls, the acids of which salts exist uncombined in the solution. The diacetate of lead then precipitates the extractive and its apotheme.

If we pass a current of sulphuretted hydrogen through the liquid precipitated by the salts of lead, and evaporate after filtering, the liquid, when sufficiently concentrated, concretes into a crystalline mass. When this mass is treated with alcohol of 0·81, sugar and bitter principle are dissolved, and nitre remains. Evaporate the

* Jour. Chem. Med. iii. 105.

alcoholic solution to the consistence of a syrup, and agitate it for a considerable time in a mixture of alcohol and ether. The liquid separates into two portions. The ether swimming on the top contains the bitter principle; and the alcohol at the bottom contains the sugar.

The bitter principle, when solid, has a yellowish-brown colour. Its taste is very bitter. When distilled it yields no ammonia. It is but little soluble in water; and the boiling-hot saturated solution becomes muddy on cooling. Ether and alcohol are its best solvents. It is insoluble in the fat oils. Its aqueous solution is not precipitated by nitrate of silver, corrosive sublimate, or acetate of lead; but it is thrown down by diacetate of lead, unless it be mixed with sugar, which prevents the salt of lead from acting on it. The alkalies render its colour deeper. Nitric acid converts it into oxalic acid.

After the leaves have been exhausted by alcohol, water dissolves from them gum, a little vegetable albumen and salts; and there remains undissolved fibrin, which, when boiled in a silver basin with potash, blackens the silver, and, therefore, contains sulphur.

6. *Arthanitite.* M. Saladin found in the root of the *Cyclamen Europeum*, or *sow wort*, a peculiar bitter principle, which he distinguished by the name of *arthanitite*, because this root is employed in medicine, under the name of *radix arthanitæ*. He obtained it in the following manner:—

An extract of the root was prepared by digesting it in water, and evaporating the solution to dryness. The dry extract was digested in boiling alcohol, till every thing soluble was taken up. The alcoholic solution being abandoned to spontaneous evaporation, the arthanitite was deposited in small crystalline grains.

It is colourless, soluble in 500 times it weight of cold water, readily soluble in alcohol, but insoluble in ether, fixed, and volatile oils. The alcoholic solution has a bitter taste, but has no action on vegetable blues. It is rendered muddy by water and by ether, and the arthanitite is completely precipitated by infusion of nutgalls. Sulphuric acid gives it a red colour; nitric acid converts it into oxalic acid. The vegetable acids dissolve it more readily than water does.

Arthanitite is said also to exist, though in small quantity, in the root of *primula veris.**

7. *Bitter principle of wormwood.* The leaves of the *artemisia absynthium*, or *wormwood*, contain a bitter principle, which was obtained by M. Caventou, by the following process:—

A very concentrated infusion of wormwood was precipitated by acetate of lead. Through the filtered liquid a current of sulphuretted hydrogen was passed, to throw down any excess of lead. The whole was filtered again, and concentrated to the consistence of an extract. This extract was digested in a mixture of 4 parts

* Berzelius, Traité de Chimie, vi. 185.

alcohol, and 1 part ether, till every thing soluble was dissolved. The bitter principle was taken up, and when the alcoholic liquor was evaporated, it remained behind, in a hard brown friable mass. It has the peculiar bitter taste which characterizes wormwood. It does not crystallize. When distilled in a retort it is completely decomposed.*

M. Mein has endeavoured to show, that this bitter principle possesses resinous characters. But from the process followed in procuring it, we see that it was soluble in water.†

8. *Colocynthite.* This bitter principle is contained in the fruit of the *cucumis colocynthis*, or *colocynth* of apothecaries. It was first obtained in a separate state by Vauquelin. The following is the process which may be employed:—

Boil the pulp of colocynth in water, evaporate the decoction to dryness, and treat the residue with alcohol, which leaves the gum but dissolves the colocynthite, together with some acetate of potash. Evaporate the alcoholic solution, and treat the residue with a small quantity of water, which dissolves the acetate and leaves the greater part of the colocynthite in a state of purity.

Colocynthite thus obtained is a yellowish-brown or reddish matter, translucent, brittle, and easily reduced to powder. It restores the blue colour to litmus paper reddened by an acid. When heated it burns with flame like a resin, and when distilled, furnishes a little ammonia. It requires five times its weight of cold water to dissolve it. It is much more soluble in hot water, and nothing is deposited when the liquid cools. It is soluble also in alcohol and ether. Chlorine throws down from the aqueous solution a precipitate soluble in alcohol. Acids and the very deliquescent salts, such as, chloride of calcium and acetate of potash precipitate it from its solution in water, under the form of a coherent and adhesive mass, which does not dissolve in water, and which appears to be identical with the colocynthite of Vauquelin.

The aqueous solution of colocynthite, is not precipitated by alkalies, or by barytes, or lime water. The protosulphate of iron, the sulphate of copper, and the nitrate of mercury precipitate it; and it is slightly precipitated by corrosive sublimate, nitrate of silver, and acetate of lead. Infusion of nutgalls throws it down copiously: the precipitate is a light yellow matter, and so thick that the vessel containing it may be turned upside down without spilling any thing. This precipitate is soluble in alcohol and in boiling water; but is deposited from this last solution as it cools.

This colocynthite is supposed to constitute the active part of the pulp used in medicine as a drastic purgative.

9. *Bitter principle of aloes.* This bitter principle has been already described while treating of *aloes*, which we placed among the gum resins, in compliance with the usual practice of writers on *Materia Medica.*

* Jour. de Pharmacie, xiv. 577. † Ann. der Pharm. viii. 61.

10. *Xanthopicrite.* This substance was detected by Chevalier and Pelletan, in the bark of the *Xanthoxylon carybœum.**

The bark was digested in alcohol, and the spirit being distilled off left an extract, which was digested first in water, and afterwards in ether. What remained undissolved was taken up with alcohol, and the alcoholic solution being evaporated crystals of xanthopicrite were deposited.

This substance has a greenish-yellow colour and a silky lustre. It has no smell, but a very bitter and astringent taste. It is not altered by exposure to the air, and produces no change upon vegetable colours. When heated it is partly decomposed, and partly sublimes unaltered.

It is but little soluble in water, and not at all soluble in ether. It is readily soluble in alcohol, especially when assisted by heat. Chlorine has but little action on it, and a solution of xanthopicrite containing chlorine may be freed from it, either by a rapid evaporation, or by saturating the chlorine with an alkali, without altering the xanthopicrite. The long-continued action of chlorine occasions the deposition of a brown-coloured precipitate.

The chlorite of soda completely decomposes xanthopicrite. Sulphuric acid gives it a brown colour; but when the acid is saturated with an alkali, the brown colour disappears. When long boiled with dilute sulphuric acid, xanthopicrite changes its nature, it loses the property of crystallizing, and when the acid is thrown down by chalk, it yields a brownish-yellow extract, having an exceedingly bitter taste.

Nitric acid gives xanthopicrite a red colour. Muriatic acid has no sensible action on it. No precipitate appears when solutions of xanthopicrite are mixed with the earthy or metalline salts. But a good many of these salts when poured into solution of xanthopicrite, throw it down in the form of orange-coloured flocks, which dissolve when water is added to the liquid.

Chloride of gold precipitates xanthopicrite, the precipitate is a compound of the chloride and of xanthopicrite. It is insoluble in water, and gives with chloride of tin the purple of Cassius, and with nitrate of silver chloride of silver.

The tincture of the *xanthoxylon carybœum* or *clavatum* is used in the West Indies as a remedy for the toothach, and according to Chevallier and Pelletan, it owes its medicinal qualities to the xanthopicrite which it contains.

11. *Berberite.* *Berberite* is a bitter tasted substance, extracted from the bark of the *berberis vulgaris* or barbery.

It was first obtained in a state of purity by M. Buchner, senior, in 1835, and its properties were afterwards determined in detail by M. Buchner and his son.† It may be separated from the bark of barbery root by the following process:

The root reduced to small pieces is digested in boiling water for some hours. This digestion is repeated till every thing soluble is

* Mag. Pharm. xvii. 75. † Jour. de Pharmacie, xvii. 40, and xxi. 309, 408.

taken up. The watery liquids thus obtained are mixed and evaporated to the consistence of a soft extract. This matter is digested in hot alcohol of 0·844 repeatedly, as long as the liquid continues to acquire a bitter taste. These tinctures are filtered, and the greatest part of the alcohol is distilled off. The residue is left in an open vessel in a cool place. In 24 hours feather-shaped crystals are deposited of a yellow colour. They are to be separated as exactly as possible from the brown and unctuous matter in which they are immersed, by subjecting them to pressure in a fine cloth, and washing them with cold water. When these crystals are treated with boiling water, they dissolve and are deposited when the liquid cools in a very bulky crystallized mass; while the greatest part of the impurities remains in solution. If this precipitate be dissolved twice successively in boiling alcohol, and allowed each time to crystallize as the solution cools, it is rendered quite pure. By this process the MM. Buchners obtained 1·3 per cent. of the weight of the bark employed of berberite.

Berberite has the aspect of a very light powder, composed of minute needles, having a silky lustre and a beautiful yellow colour. When the alcoholic solution is cooled very slowly, the crystals are small prisms united in groupes.

It has no smell, but its taste is intensely bitter, and it continues long in the mouth. It has no action whatever on vegetable colours, excepting that it renders litmus paper green. It is very little soluble in cold water, yet it communicates a yellow colour to that liquid. At the temperature of 59° it requires 500 times its weight of water to dissolve it. At the temperature of 54°, 1 part of berberin dissolves in 250 parts of alcohol of 0·844. Boiling water and alcohol dissolve it in every proportion, but most of it falls down again when the solutions cool. Oils of lavender and turpentine only assume a very faint shade of yellow when left in contact with berberite. It is quite insoluble in ether, both cold and hot. It is insoluble also in bisulphuret of carbon and naphtha.

When concentrated sulphuric acid is poured on berberite, a solution takes place, the liquid assumes an olive-green colour, and the berberite is destroyed. When the liquid is diluted with water, it loses its colour, and a deep-brown precipitate falls insoluble both in alcohol and ether. It is dissolved by the caustic alkalies, and thrown down again by acids in brown flocks.

Nitric acid dissolves it with a strong effervescence, forming a deep-red liquor. When heated, the red colour vanishes, the solution becomes yellow, and at last almost colourless, and crystals of oxalic acid are deposited.

It is precipitated from its solutions by concentrated sulphuric, nitric and muriatic acids; by liquid phosphoric acid, and in general by all acids, which have a strong affinity for water. Acetic acid, tartaric, racemic, citric and oxalate acids dissolve berberite like water. But the infusion of nutgalls or tannin throws it down in yellowish-brown flocks.

The alkalies and several earthy bodies render the colour of berberite less distinct, and form compounds, which allow the yellow colour to appear, when these alkaline bodies are saturated with an acid. When ammonia is poured into a solution of berberite, it strikes a yellowish-brown colour. It dissolves a little berberite but not more than the same quantity of water would do. If we heat the liquid to drive off the ammonia, and then evaporate in a gentle heat, small brown crystals are deposited, having the bitter taste of berberite. When heated with potash they give out the smell of ammonia. When treated with an acid they assume the yellow colour of berberite.

Solution of potash gives berberite a reddish-brown colour without disengaging any ammonia. If we boil this solution most of the berberite comes to the surface and melts, and on cooling and washing has a liver-brown colour, a resinous aspect and a bitter taste. It is little soluble in water, but more soluble in alcohol. The alcoholic solution being evaporated gives small brown crystals. They dissolve in acetic acid without changing their colour. But muriatic or any other strong acid causes them to resume the yellow colour of berberite. Soda acts precisely as potash. Lime-water and solution of alum have no sensible action on the solution of berberite.

With most of the solutions of the metallic oxides it forms precipitates, insoluble in water or nearly so, and the liquid loses its colour.

It is thrown down yellow by nitrate of mercury, corrosive sublimate, nitrate of silver, chlorides of tin, nitrate of cobalt, tartar emetic and chloride of manganese. Perchloride of iron, nitrate of bismuth and chlorides of gold and platinum throw it down orange. Sulphates of copper and nickel throw it down greenish-yellow. Acetate and subacetate of lead occasions no precipitate, even after standing 24 hours. Nor is it thrown down by sulphate of zinc and the protosalts of iron.

A current of chlorine gas passed over dry berberite gives it a red colour, and it becomes easily soluble in water. If we continue the current, a blackish-brown precipitate falls, and the solution becomes gradually light-brown. The precipitate is tasteless and insoluble in water, partly soluble in boiling alcohol, but readily soluble in dilute potash.

Berberite is readily destroyed by heat. At a heat a little above that of boiling water it assumes a reddish tint, but resumes its yellow colour on cooling. Heated on platinum foil it melts, swells, gives out a disagreeable smell, burns with flame, and leaves a charcoal difficult to incinerate. When distilled it gives out water at 212°, assumes a brown colour at 266°, melts at 320°, and a yellowish liquid distils over. At 428° it swells and leaves a charry residue, having a strong metallic lustre. What passes over is alkaline.

It was analyzed after being dried at 230°, and found composed of

Carbon	61·23 or 33 atoms	=	24·75	or per cent.	60·74
Hydrogen	5·49 or 18 atoms	=	2·25	— —	5·52
Azote	4·03 or 1 atom	=	1·75	— —	4·29
Oxygen	29·25 or 12 atoms	=	12·00	— —	29·45
	100·00		40·75		100

The compound of berberite and oxide of silver consisted of

Oxide of silver . .	25·98 or 14·5
Berberite . . .	74·02 or 39
	100·00

The number 39 does not correspond well with 40·75, the atomic weight determined by analysis, unless we suppose, that in the state in which it was analyzed it contained an atom of water.

It was administered by M. Buchner to the extent of 10 grains, and found a powerful tonic. Berberite answers very well as a dye-stuff and gives a fixed yellow colour without any mordant. Chloride of tin improves the colour. When the cloth is previously impregnated with sulphate of copper, a beautiful greenish-yellow colour is obtained. With nutgalls the colour is yellowish-brown.

12. *Lupinite.* Cassola* has extracted from the beans of the *lupinus albus*, a peculiar bitter substance to which he has given the name of *lupinite*. The meal of these beans is treated with anhydrous alcohol. The solution being evaporated to dryness, the *lupinite* remains.

It has a green colour, is translucent, and may be melted. It is soluble in anhydrous alcohol and ether. Its taste is bitter. But it is not probable that it was obtained by Cassola free from an admixture of other vegetable substances.

13. *Phloridzite.* This is a name given by Dr Koninck, to a bitter-tasted principle, which exists in the bark of the trunk and roots of the apple, pear, cherry, and plum-trees.† Its existence was first noticed by Professor Geiger of Heidelberg,‡ but it was first obtained in a separate state, and its characters determined, by Dr Koninck.§

The preparation of this substance is very simple. The fresh bark of the root of the apple-tree is boiled for two hours in a quantity of water sufficient to cover it. This water is decanted off, and the boiling repeated with a second portion, and this last decoction must be kept separate from the first. It commonly deposits in 24 hours, a considerable quantity of granular crystals of phloridzite, which, when dissolved in distilled water, and treated with animal charcoal, are rendered quite pure. We obtain an additional quantity by evaporating the liquid down to $\frac{1}{5}$th. In this state of concentration, it deposits the whole phloridzite which it contains, when left at rest

* Jour. de Chi. Med. x. 688.

† Hence the name phloridzite, from φλοιος, *bark*, and ῥιζα, *root*.

‡ Handbuch der Pharmacie, ii. 62.

§ Liebig's Jour. der Pharm. xv. 75 and 258.

for a couple of days. The bark of apple-tree root, when treated in this way, yields about 3 per cent. of phloridzite.

By another process we may obtain about 5 per cent. It consists in digesting the *fresh* bark of the root in weak alcohol, at about the temperature of 122°. The digestion is continued from 8 to 10 hours. The greater part of the alcohol is then distilled off, and the residue set to crystallize. The first crystals obtained in this way are whiter than those obtained by the first process. They are to be purified in the same way as the others.

Phloridzite thus obtained, has a dull white colour, with a shade of yellow, and is crystallized in silky needles. It may be also obtained in tables. Its taste is intensely bitter. Water at 72°, or lower, dissolves only the thousandth part of its weight of it. But from 76° to 212°, it dissolves it in all proportion. It is very soluble in absolute alcohol, at the common temperature of the atmosphere; but it is very little soluble in ether. It has no action on vegetable colours. Its specific gravity is 1·4298.

When heated to 212°, it loses all its water of crystallization; but when dried in the ordinary temperature only, it retains 7 per cent. of that liquid. When the water is once driven off, it is not again absorbed, even in a moist atmosphere.

Phloridzite melts at 226°½, and boils at 350°½. At 379°½ it begins to be decomposed, a small quantity of benzoic acid being formed, some acetone, and a brown oil heavier than water.

The concentrated acids dissolve it without decomposition, while it retains its water. But when anhydrous, it is strongly attacked by sulphuric acid, and forms a reddish brown solution. Nitric acid behaves in the same way while cold, but by heat it converts it completely into oxalic acid. Muriatic acid converts it into a white insoluble substance which separates.

When boiled with dilute sulphuric acid for 8 or 10 hours, it is not converted into sugar. The alkalies and concentrated acetic acid dissolve it without alteration.

Chlorine, bromine, and iodine, act upon it with violence, producing a brown resinous substance, insoluble in water, but soluble in alcohol. Much heat is evolved, and muriatic acid, hydrobromic acid, and hydriodic acid, are respectively given out.

Persulphate of iron gives, with solution of phloridzite, a yellowish-brown precipitate, and perchloride of iron, a very dark-brown precipitate. But the protosulphate of iron has no action. The same remark applies to the neutral metallic salts. Diacetate of lead throws down a copious white precipitate, which becomes yellow when dry.

Chlorite of lime (*bleaching powder*) gives it a light-yellow colour, which in a few days becomes brown, without occasioning any precipitate. Aqueous solution of chlorine throws down a yellow precipitate. Gelatine does not produce any alteration on its solutions.

We have two analyses of phloridzite. The first by M. Chr. Petersen,* and the second by Dr Koninck.† But they differ so

* Jour. der Pharm, xv. 178. † Ibid. xv. 261.

much from each other, that it is scarcely possible that they can have operated upon the same substance in a state of purity. The results are as follows :—

	Petersen.	Koninck.
Carbon .	56·16	51·0
Hydrogen .	5·82	5·6
Oxygen .	38·02	43·4
	100·00	100

The first of these numbers corresponds with the following atomic constitution.

4 atoms carbon . .	= 3
2½ atoms hydrogen . .	= 0·3125
2 atoms oxygen . .	= 2
	5·3125

while Dr Koninck's analysis gives us

3 atoms carbon . . .	= 2·25
2 atoms hydrogen . . .	= 0·25
2 atoms oxygen . . .	= 2
	4·50

A new analysis will be requisite to settle these discordant results.

14. *Bitter principle of variolaria amara*, or *picrolichenite*. This substance was discovered in 1832, by M. Alms of Penzlin in Mechlenburg* in the *variolaria amara*, a lichen which grows in great abundance on the bark of the beech. His mode of obtaining it was this. It was digested in cold alcohol, till every thing soluble was taken up. The alcohol being distilled off, left a great deal of chlorophylle resin, and a light-green crystalline matter, amounting to about 8 per cent. of the lichen employed. This, when purified by weak potash, constitutes the bitter principle.

It crystallizes in octahedrons, with a rhomboidal base, and is not altered by exposure to the atmosphere. It has no smell, but a very intense bitter taste. Its specific gravity is 1·176.

It is a neutral substance, insoluble in cold water, but slightly soluble in boiling water, and very soluble in alcohol, and ether, and bisulphuret of carbon. When left under a glass alongside of another vessel containing ammonia, it is gradually converted into a red resin, quite destitute of bitterness.

Sulphuric acid forms with it a colourless solution, precipitated by water. Nitric acid has but little action. Muriatic acid and phosphoric acid are inert. Oil of turpentine, naphtha, and various fixed oils dissolve it. Carbonate of potash takes up a little of it, which is thrown down again by water. Potash ley forms with it a wine-red solution. It melts when heated a little above the fusing

* Jour. der Pharmacie, i. 61.

point of sulphur. When the heat is increased, the colour is deepened, and the picrolichenite decomposed.

M. Alms conceives that it may be useful in medicine, from some analogy in the smell to the bitter matter of anchovies. But this opinion has not been put to the test of experiment.

15. *Scillitite.* This is the peculiar substance to which the bulb of the *scilla maritima*, or squill, owes its medicinal qualities. Its properties were investigated by Vogel, 1812, who pointed out its peculiar nature, and gave it the name by which it is distinguished.* It may be obtained by the following process. The juice of the bulbs being expressed was boiled for a few minutes, and a quantity of citrate of lime which appeared was separated. It was then evaporated to dryness, and the dry residue digested in alcohol as long as that liquid took up any thing. The alcoholic solution was evaporated to dryness, and the residue (which consisted of scillitin and tannin) was redissolved in water. Acetate of lead was dropped in to throw down the tannin. The liquid was filtered, and the excess of lead which had been added was separated by means of a current of sulphuretted hydrogen gas. The liquid being again filtered, was evaporated to dryness to drive off the acetic acid from the acetate. The dry mass was scillitite, mixed with a little sugar, from which it was not in Vogel's power to separate it.

Scillitite thus obtained is white and transparent, and breaks with a resinous fracture. It is easily reduced to powder. It absorbs water rapidly from the atmosphere, and becomes at first a viscid mass, and at last quite fluid. Its taste is intensely bitter, leaving a slight impression of sweet from the sugar with which it is mixed. It dissolves readily in water, and gives it a mucilaginous consistency like gum. It dissolves likewise very readily in cold alcohol of 0·817, and still more readily in that liquid while hot. When heated, it swells prodigiously, and gives out a distinct odour of caromel. When treated with nitric acid no saclactic acid is formed.

The scillitite of Vogel, contains a considerable quantity of uncrystallizable sugar. Tilloy pointed out the following method of freeing it from this foreign body.† Dissolve the scillitite in alcohol, and mix the alcoholic solution with ether. The sugar with a portion of the scillitite is precipitated, while the greatest part of this body remains in solution, in a state of purity. Tilloy's process for obtaining scillitite is as follows:—

Macerate dry squills in alcohol, decant, and distil till the residue is reduced to the consistency of a syrup. Mix this syrup with spirits of the specific gravity 0·842. There remains an extractive matter which must be well kneaded with spirits. Evaporate the alcoholic solution to the consistence of an extract. Digest the extract in ether which dissolves a yellow-coloured solid fatty matter, having an acrid and bitter taste, insoluble in water, but very soluble in alcohol, ether, and the alkalies. The residue insoluble in ether, is treated with

* Ann. de Chim. lxxxiii. 147. † Jour. de Pharmacie, xii. 635.

water, which separates a great deal of scillitite in yellow flocks. These flocks are collected on a filter. This scillitite is softened in hot water, and collected in a mass. When cold it is brown and brittle. Its taste is very acrid and bitter. When heated it melts, swells up, and gives out a smell at first aromatic, and then urinous. It is insoluble in ether, but soluble in alcohol. The dilute acids have no action on it. A single grain of this substance is sufficient to kill a moderate-sized dog.

More lately, or in 1835, M. Landerer obtained scillitite in crystals, and consequently much purer by the following process:—*

The squill was pounded and digested in dilute sulphuric acid. The bitter-tasted solution was boiled down to one half, saturated with lime, and left at rest for 3 days. The precipitate was dried and digested in alcohol of 0·838. The alcoholic solution had a bitter but not an acrid taste. Being left to spontaneous evaporation prismatic crystals were deposited. 18 lbs. of squill furnished only 30½ grains of these crystals.

They had a bitter taste, restored the blue colour of reddened litmus paper. They were soluble in 120 times their weight of alcohol, insoluble in water, fixed and volatile oils, and according to Landerer, saturated acids, and consequently possessed the characters of an alkali. These crystals can be extracted only from fresh squills.

16. *Bitter principle of China nova.* This substance was discovered, in 1836, by Dr Winkler, of Zwingenberg, in the bark of the *China regia*, and *China nova;* but it exists in greatest abundance in the last of these barks. Winkler extracted it by the following process:—†

The bark may be exhausted by alcohol, and the extract treated with water, to get rid of the Chinovic acid; the residue is to be redissolved in alcohol, and the tannin thrown down by isinglass; or the alcoholic solution may be treated with animal charcoal, digested with ether, and evaporated. But a greater quantity of *Chinova bitter* is obtained by digesting the pulverized bark in ether, and evaporating the solution. The residue is treated with alcohol, and the alcoholic solution is digested with animal charcoal, and the bitter principle is thrown down by ammonia. Thus obtained it is white, and free from Chinovic acid.

Thus obtained, it is neutral, and has no resemblance to the alkalies from cinchona, but approaches more to the resinous bitter substances.

When heated it first melts like resin, then by an augmentation of temperature, it gives out dense white fumes, becomes brown, and is charred. There passes over into the receiver a yellowish acid liquid, and a light-brown oil, having a burning taste and a strong smell, analagous to that of camphor. When this product is saturated with caustic potash, no ammonia is disengaged.

* Ann. der Pharmacie, xvi. 225. † Ibid. xvii. 161.

When heated in a retort with quicklime and water, there comes over a neutral colourless liquid, and a green oil, having the smell of oil of peppermint. No ammonia is formed, showing that chinova bitter contains no azote.

It was subjected to analysis by Dr Buchner, jun., who found it composed of

Carbon	61·64
Hydrogen	8·58
Oxygen	29·78
	100·00

Now, this is precisely the constitution of parrillina.

Buchner found that when exposed to a temperature of 248°, 100 parts of chinova bitter lost 8·53 of its weight.

If we substract this water from the above constituents, we have anhydrous chinova bitter, composed of

Carbon	61·64 or 22	atoms =	16·5
Hydrogen	7·63 or 16½	atoms =	2·0625
Oxygen	22·20 or 6	atoms =	6
			24·5625

The water driven off is obviously 2 atoms, so that hydrous chinova bitter is composed of C^{22} $H^{16\frac{1}{2}}$ O^{6} + 2 (HO).

But it was analyzed in Liebig's laboratory with great care, by M. Petersen, who obtained

Carbon	66·61 or 15 atoms	=	11·25	or per cent.	67·16
Hydrogen	8·89 or 12 atoms	=	1·5	— —	8·95
Oxygen	24·50 or 4 atoms	=	4	— —	23·89
	100*		16·75		100·00

This last formula must represent the true constitution of the bitter principle of *china nova*.

CHAPTER XI.

OF PRODUCTS OF THE DESTRUCTIVE DISTILLATION OF VEGETABLE SUBSTANCES.

For the discovery of the greater part of the substances described in this Chapter, we are indebted to M. Reichenbach. Some of them, as naphtha, petrolene, and aspaltene, are found in matters existing on the earth. But it is probable that they have been formed originally by the destructive distillation of vegetables or trees, in some great processes of nature. Our knowledge of these bodies is still too scanty to enable us to distribute them as they ought to be among the other groupes of vegetable substances, to

* Ann. der Pharm. xvii. 164.

which they undoubtedly belong. We can only state the facts that have been hitherto ascertained.

SECTION I.—OF PERSIAN NAPHTHA.

This liquid appears to exude from the earth in various parts of Persia in considerable quantity. Pliny informs us that it is very abundant in the neighbourhood of Babylon. But from the account which he gives of it, we may infer, that he had never seen a specimen of it, or at least had never examined it. It occurs also at Rangoon in India, and specimens from that quarter were examined some years ago by Dr Christison,* and Dr Gregory.†

Persian naphtha, as it is collected on the spot, is very nearly, but not quite colourless. It has a bituminous smell, and a specific gravity of 0·753. It begins to boil at 320°, but the boiling point gradually rises to 352°.

The petroleum of Rangoon may be obtained in immense quantity, by digging a few feet into the soil. In Hindostan it is employed to pitch all kinds of wood-work, and is likewise a favourite remedy for rheumatism, being applied by way of friction. At the ordinary temperature of this country, it is a soft substance of the consistence of lard. Its specific gravity at 60° is 0·880. At 90° it melts and becomes more limpid as the temperature rises. When distilled at a low heat, it yields about a sixth part of its weight of colourless naphtha.

This rectified naphtha has a specific gravity (as determined by Dr Gregory) of 0·765, and boils at 200°? When treated with concentrated sulphuric acid, and strong caustic potash alternately, and finally rectified, its specific gravity was 0·744, and it boiled at 180°. It had the smell and most of the properties of eupion, though the small quantity in Dr Gregory's possession did not enable him to bring it to a state of purity. Dr Christison had previously extracted paraffine from the Rangoon petroleum. We may conclude from these facts, that this petroleum, and the naphtha which it contains, has been produced by the destructive distillation of vegetable bodies.

Persian naphtha was analyzed by Blanchet and Sell, who obtained

Carbon	83·90
Hydrogen	14·21
	98·11‡

These numbers lead to the formula—

1 atom carbon	0·75	or per cent.	85·7
1 atom hydrogen	0·125	— —	14·3
	0·875		100·0

Doubtless Persian naphtha is composed of an equal number of atoms of carbon and hydrogen, probably 12 atoms of each.

* Edin. Trans. xiii. 118. † Ibid. p. 124. ‡ Ann. der Pharm. vi. 309.

SECTION II.—OF COAL NAPHTHA.

From the experiments already made, there are strong reasons for concluding, that the naphtha obtained by distilling the petroleum from Trinidad, and the asphalt from the Dead Sea, is precisely similar to that procured by rectifying coal tar. It is probable also that the naphtha from Amiano is of the same nature.*

Naphtha is limpid and colourless, like water. It has a bituminous smell, a specific gravity of 0·817; and Reichenbach supposed that it possesses the characters of oil of turpentine. It burns with a strong yellow flame, giving out much smoke.

It is insoluble in water. Alcohol dissolves about $\frac{1}{5}$th of its weight of it. Ether, petroleum, fixed oils, and volatile oils, combine with it in every proportion. It dissolves wax by the assistance of heat, and deposits a portion of it again as it cools. Caoutchouc swells in it to more than thirty times its original bulk, and becomes gelatinous and transparent, but scarcely dissolves. But by long boiling, a solution is effected.

Saussure found that 1 volume of vapour of naphtha requires 14 volumes of oxygen gas for complete combustion, and there remain, after the combustion, 8 volumes of carbonic acid gas.

Unverdorben, by cautiously rectifying naphtha, resolved it into various liquids, differing from each other in their boiling point. Blanchet and Sell found the boiling point of coal naphtha to vary from 302° to 356°. They analyzed a specimen, having a specific gravity of 0·911, and boiling at 320°, and obtained

Carbon	87·94
Hydrogen	9·07
	97·01†

It doubtless contains oxygen, for it converts potassium into potash with great rapidity. If we admit the loss to be oxygen, the constitution will be

39 atoms carbon	= 29·25	or per cent.	87·97
24 atoms hydrogen	= 3·00	— —	9·02
1 atom oxygen	= 1·00	— —	3·01
	33·25		100

This is very nearly

4 × 10 atoms carbon
3 × 8 atoms hydrogen
1 atom oxygen.

Here we see the analogy between coal naphtha and the petrolene of Boussingault, described in the next Section.

Hess analyzed it a great many times with the same result.

* This, however is somewhat doubtful, as de Saussure, by rectifying Amiano naphtha three times, reduced its specific gravity to 0·758, which is considerably lower than the specific gravity of coal naphtha.

† Ann. der Pharm. vi. 312.

There was always a deficiency, varying from 3 to 6 per cent. But when it was distilled along with water, the naphtha that came over was found composed of

Carbon	86·42
Hydrogen	14·08
	100·50*

Obviously equal atoms of carbon and hydrogen. The substance containing oxygen is evidently the yellow oil which remains in the retort.

SECTION III.—OF PETROLENE.

This name has been given by M. Boussingault† to a substance which he extracted from the bitumen of Bechelbronn, in the department of the *Bas Rhine*. This bitumen is viscid, and has a very deep-brown colour. It is known in the neighbourhood under the name of *stone oil*, and is employed as a substitute for grease for machinery. Alcohol of 0·817, when digested on it, assumes a brown colour, and the bitumen becomes much more consistent than before. It dissolves easily, and completely in ether.

It loses no weight, though kept at the temperature of 212°. But when the heat is raised to 446°, drops of an oily liquid pass over, but very slowly. It is this oily matter to which Boussingault has given the name of *petrolene*. He mixed together about 22 imperial gallons of water with from 12 to 15 pounds of the bitumen, and distilled in an alembic. The oil that comes over is very liquid, but has a brown colour. It is to be dried over chloride of calcium, and then rectified in a retort. It is now pure.

Petrolene, thus obtained, has a pale yellow colour, little taste, but a bituminous odour. Its specific gravity at 70° is 0·891. It remains liquid, though cooled down to 10°½. It stains paper like the volatile oils, and burns with a lively flame, giving out much smoke. It boils at 536°. Alcohol dissolves it in small quantity; but it is much more soluble in ether.

Boussingault subjected it to analysis, and obtained

Carbon	87·04
Hydrogen	12·21
	99·25

The specific gravity of the vapour of petrolene was found to be 9·415.

Now, 87·04 carbon, and 12·21 hydrogen, approach the formula—

10 atoms carbon . . .	7·5
8 atoms hydrogen . . .	1
	8·5

which represents the constitution of oil of turpentine, and several other volatile oils. And

* Poggendorf's Ann. der Phys. xxxvi. 434.
† Ann. de Chim. et de Phys. lxiv. 141.

20 volumes carbon vapour weigh . .	8·3333
16 volumes hydrogen gas — . .	1·1111
	9·4444

It is obvious from this, that the true constitution of petrolene is

20 atoms carbon . . .	= 15
16 atoms hydrogen . . .	= 2
	17

So that an integrant particle contains just twice as many atoms as an integrant particle of oil of turpentine.

SECTION IV.—OF ASPHALTENE.

When the bitumen of Bechelbronn has been treated with alcohol, it becomes much more solid than it was at first. The alcohol dissolves the petrolene, which is easily obtained by subjecting the alcoholic solution to distillation. But we cannot, by alcohol, deprive the bitumen of the whole of its petrolene. M. Boussingault succeeded in getting quit of the whole of it, by keeping it at a heat of 482°, till it ceased to lose weight. The heat must be continued at least fifty hours, when we employ only 30 grains of matter. To the substance remaining after this treatment, Boussingault has given the name of *asphaltene*.* Its properties, as determined by him, are as follows:—

It is black, and has a great deal of lustre. It breaks with a conchoidal fracture, and it is heavier than water. When heated to about 572°, it becomes soft and elastic. But it undergoes decomposition before it can be melted. It burns like the resins, leaving a bulky charcoal. When pure, it leaves no residue after complete combustion.

M. Boussingault analyzed asphaltene, and obtained

Carbon	74·25 or 19 atoms	= 14·25	or per cent.	74·51
Hydrogen	9·96 or 15 atoms	= 1·875	— —	9·81
Oxygen	15·79 or 3 atoms	= 3	— —	15·68
	100·00	19·125		100

Now, 19 : 15 : : 20 : 15·8.

From this, it is likely that asphaltene is nothing else than petrolene united with oxygen. On that supposition, the atomic weight would be 20.

It would appear that the bitumen of Bechelbronn is a compound of petrolene and asphaltene. In the proportion of

1 atom petrolene	= 17	or per cent.	14·53
5 atoms asphaltene	= 100	— —	85·47
	117		100·00

* Ann. de Chim. et de Phys. lxiv. 148.

SECTION V.—OF PARAFFIN.

This substance was discovered by M. Reichenbach, of Blansko, in Moravia, and made known to the chemical public in 1830.* It exists in the tar obtained by the distillation of various substances, both animal and vegetable. But it is from vegetable tar, and especially from the tar of the beech tree, that we obtain it in greatest abundance, and with most facility.

If we distil to dryness the tar obtained from the beech, three liquids will be found in the receiver, a light oil swimming on the top, below it an aqueous liquid having an acid taste, and a heavy oil at the bottom. This last liquid is to be distilled a second time. As soon as what comes over begins to get thick, and to deposit scales, the receiver must be changed. The heat is now raised till what comes over becomes black and thick. We find in the receiver an oil, containing numerous scales of paraffin. There are two ways in which this paraffin may be separated.

The first method is to agitate the liquid in the receiver, with six or eight times its weight of alcohol of the specific gravity 0·837. After an interval of repose, a viscid mass subsides from the liquid. This matter is to be repeatedly washed with alcohol till it is transformed into small colourless scales. These scales are to be dissolved in absolute alcohol by the assistance of heat. On cooling the paraffin is deposited in small white scales and needles. To render it perfectly pure, it must be repeatedly dissolved in hot alcohol, and crystallized by cooling. This process, of course, is expensive. We must use a great deal of alcohol, and a considerable portion of the paraffin remains in solution.

The second process is more economical. The heavy oil from the tar is distilled repeatedly. It is then mixed with strong sulphuric acid by small quantities at a time ($\frac{1}{20}$th of its weight) till the mixture is quite black and liquid. Heat is evolved and sulphurous acid formed. The quantity of acid requisite, amounts to from $\frac{1}{4}$th to $\frac{1}{2}$ the weight of the oily liquid. If the heat produced does not amount to 212°, we must raise the mixture to that temperature artificially. The mixture, after being thus heated, is to be left at rest for 12 hours or more, in a stove, whose temperature is not lower than 122°, that the paraffin may not become solid. At the end of that time, we find at the surface a liquid perfectly colourless. This liquid, which is a combination of paraffin, and a peculiar oil, is to be decanted off. Or, if we allow the whole to get cold, this uppermost liquid will congeal, and may be taken off under the form of a crust. Let it be broken, washed with water, and exposed to pressure between folds of blotting paper. The oil is absorbed by

* Schweigger's Journal, lix. 436; lxi. 273; and lxii. 129. It was discovered by Dr Christison, Professor of Materia Medica in the University of Edinburgh, about the same time that Reichenbach was investigating its properties. He obtained it by distilling the petroleum of Rangoon; and, in 1831, read a notice of it to the Royal Society of Edinburgh, under the name of *petroline*.

the paper, and the paraffin remains in the state of white scales which are purified by solution in absolute alcohol assisted by heat. We obtain a colourless mass, transparent like glass, scarcely flexible, and leaving no oily stain when pressed against unsized paper.

If the combination of paraffin and oil does not separate from the sulphuric acid, we distil the whole. Water, sulphuric acid, and an oil evaporate. As soon as this last, which contains the paraffin, begins to thicken, it is collected separately, and treated anew with sulphuric acid and alcohol, as at first. If the paraffin be not entirely colourless, we must treat it again with sulphuric acid, and leave the mixture a long time in a state of rest, in a temperature not under 122°.

Paraffin thus obtained is a transparent crystalline substance, of a white colour, and destitute of taste and smell. It has nearly the feel of *cetin*. It is ductile, though the scales do not readily unite, and when rubbed assumes a waxy lustre. It is not volatile at the ordinary temperature of the atmosphere. When heated to 110° it melts into a colourless, transparent oil. At a still higher temperature it boils, and may be distilled over without alteration. When heated over a lamp in a platinum spoon it melts, and then catches fire, and burns with a white flame without smoke, and leaves no residue. Its specific gravity is 0·870.

It has very little tendency to combine with other bodies. Hence the name *paraffin* (*parum affinis*) by which M. Reichenbach has distinguished it. Chlorine, whether dissolved in water or in the gaseous state, has no action on it. Nor is it acted on or altered by sulphuric, muriatic, nitric, acetic, oxalic, or tartaric acids, nor by solutions of potash, ammonia, lime, barytes, strontian, the alkaline carbonates, hydrate of lime, nor by potassium, when even in a state of fusion. Red oxide of lead and binoxide of manganese, are equally without action on it. When it is melted with sulphur, phosphorus, or selenium, it dissolves only a minute quantity of these bodies, and undergoes no sensible alteration in its qualities. It cannot be combined by fusion with camphor, napthalin, benzoin, nor pitch. But it may be united by heat with stearin, cetin, bees' wax, and common rosin. Melted hogs' lard and mutton suet combine with it, but separate on cooling. Olive oil, while cold, is a bad solvent of paraffin; but it dissolves it with facility when hot. The same remark applies to oil of almonds. But oil of turpentine and coal naphtha dissolve it with facility, without the assistance of heat.

Ether is its best solvent. 100 parts of that liquid dissolve 140 of paraffin at the temperature of 77°. When the liquid is cooled a little below that point the whole becomes solid, in consequence of the crystallizing of the paraffin. Cold alcohol dissolves very little of it. 100 parts of boiling alcohol dissolve 3·45 parts of paraffin, but the paraffin crystallizes when the liquid cools. Paraffin has no action on vegetable blues.*

* Poggendorf's Annalen, xxiv. 173.

As paraffin, so far as we know, does not enter into any definite compounds with other substances, we have no means of determining its atomic weight; but M. Jules Gay-Lussac has subjected it to analysis by means of oxide of copper. And found its constituents to be

Carbon	84·04 or 1 atom	= 0·75	or per cent. 85·71
Hydrogen	13·87 or 1 atom	= 0·125	— — 14·29
	97·91*	0·875	100·00

It is, therefore, another substance belonging to the numerous tribe of *carbo-hydrogen;* but how many atoms of each constituent enters into its composition, we do not know. As it is easily distilled over, there would be no great difficulty in determining the specific gravity of its vapour. This would furnish data for calculating its atomic constitution.

A substance has lately been discovered in Moldavia, in considerable masses, which has been distinguished by the name of *fossil wax of Moldavia.*

M. Magnus has subjected this wax to analysis, and found that it consisted, in a great measure, of paraffin.†

M. Laurent has shown that paraffin may be obtained also by distilling the shale, which is so abundant in the coal-beds of Great Britain.‡

If paraffin could be obtained at a sufficiently cheap rate, it might be substituted for wax in many cases.§

SECTION VI.—OF EUPION.‖

This substance was also discovered by Reichenbach, and its characters described by him in 1831.

It is obtained by distilling, in a retort, the tar which is procured by decomposing animal muscle, bone, leather, or horn, by distillation in the dry way. But it may be obtained also from vegetable tar and from coal tar. If 8 parts of tar be put into the retort, 5

* Poggendorf's Annalen, xxiv. 180.

† Ann. de Chim. et de Phys. lv. 218. See an account of it among the fixed solid oils, page 448.

‡ Ibid. liv. 392.

§ A substance sent to Dr Trommsdorf by M. Fikentscher of Redwitz, and discovered in a bed of peat, appears, from the experiments of Trommsdorf, to resemble paraffin very closely in its properties, though it differs in its composition. When purified by solution in alcohol and evaporation, it was in soft white plates, having a fatty lustre. The only difference observable between the properties of this substance and those of paraffin is, that it does not melt till heated to 219°, while paraffin melts at 110°. It was analyzed by Trommsdorf, junior, and found composed of

Carbon	90·91 or 2 atoms	= 1·5	making per cent. 92·3
Hydrogen	7·56 or 1 atom	= 0·125	— — 7·7
	98·47	1·625	100·0

See Ann. der Pharmacie, xxi. 126.

‖ Poggendorf's Annalen, xxiv. 173.

are to be distilled off. These 5 parts are again put into a retort and 3 parts of them distilled off. This new liquid is to be mixed with sulphuric acid (a little at a time), in the proportion of 10 ounces avoirdupois, of acid, for every imperial gallon of tar employed; and the mixture is to be well agitated. We obtain a red-coloured liquid, together with a subtile transparent yellow liquid. This last liquid is separated from the other, and mixed in a retort with its own weight of sulphuric acid, and $\frac{3}{4}$ths of it is distilled off. What comes over is a colourless liquid, which is washed with potash ley; and, after digesting for some time, the oil is separated, mixed with half its weight of sulphuric acid, and distilled anew. The liquid, which comes over, is to be washed with potash ley, and then decanted off. It is now mixed with pure water, and distilled very slowly till $\frac{3}{4}$ths have passed over into the receiver. What remains is a mixture of paraffin and eupion. The distilled portion is left under a vacuum for 24 hours. It is then mixed with a few grains of potassium, and raised to the boiling temperature. This occasions the separation of reddish-brown flocks. The process is repeated till the reddish-brown flocks cease to form, and the potassium retains its metallic lustre. The liquid, being decanted off, is *eupion.*

Reichenbach has found more lately,* that eupion may be obtained much purer by distilling rapeseed oil. This oil is distilled in an iron retort with a moderate fire, so that the oil may not pass over. The first and the last portions distilled over are separated from the rest, because they contain foreign matter. The middle portion is liquid, and has a specific gravity of 0·86. When distilled again it is as liquid as water, and has a specific gravity of 0·83. Its colour is yellow. When again rectified its specific gravity becomes 0·77. If it be now mixed with concentrated sulphuric acid, and distilled again, washed with potash ley, and finally purified with sulphuric acid, as specified above, its specific gravity is reduced to 0·70. Let it be now distilled in a temperature of 122°, and again rectified in a temperature of 97°, and finally distilled at 97°. From chloride of calcium, we obtain it pure.

It is a colourless liquid like water, which does not become solid, though cooled down to —4°. It has no taste, but a smell like that of blossoms; is not altered by exposure to the air; is a non-conductor of electricity. It feels neither fatty nor harsh, and has no effect upon litmus or turmeric paper. Its power of dispersing light is exceedingly small. It boils at 116°½· and if it be quite pure it may be distilled over without leaving any residue whatever. When dropt upon water, it does not, like oil, spread on the surface. While cold it does not take fire from the flame of a candle; but when boiled over a lamp in a platinum spoon, it may be made to burn with a lively flame without giving out any smoke.

Its specific gravity is 0·655. When impure eupion is heated from 66° to 336°, its volume increases about a fifth part.

* Jour. für Pract. Ch. i. 377.

It is quite insoluble in water, absolute alcohol dissolves it in all proportions. But it is very little soluble in alcohol of specific gravity 0·82. When we add to the solution of anhydrous alcohol, alcohol containing water, the eupion separates in unctuous drops. It unites in all proportions with ether, and with most of the volatile oils. Acetic ether dissolves about the third of its weight of eupion. Bisulphuret of carbon, oil of turpentine, naphtha, olive oil, and oil of almonds may be mixed with it readily, even while cold.

Eupion dissolves readily chlorine at the common temperature of the atmosphere, and still more easily bromine. But when the solution is heated, these bodies separate without occasioning any alteration. Iodine dissolves in it cold, and still more readily hot, and crystallizes in part as the solution cools. Phosphorus, sulphur, and selenium are not dissolved, while the eupion is cold, but readily when that liquid is heated. When the solution cools, the whole of the sulphur and phosphorus and the greater part of the selenium precipitates.

Naphthaline, camphor, stearin, cetin, cholesterin, paraffin, and balsam of copaiva, are soluble in cold eupion, and still more soluble when that liquid is hot. Tallow dissolves in it at the temperature of 77°; but at 68° the liquid becomes muddy, probably, because the stearin precipitates while the olein remains in solution in the eupion. Bees' wax is completely dissolved by hot eupion, but when the liquid cools, the greater part of it precipitates. Rosin dissolves only partially when the eupion is cold; but completely by the assistance of a boiling heat. Benjoin, animé, copal, and lac, dissolve only partially, even when assisted by ebullition. When the liquid cools, these substances are again deposited either totally or partially. Caoutchouc swells enormously in eupion, yet it does not dissolve at the temperature of 212°; but the solution is complete when the eupion is boiled. The solution does not become dry by simple exposure to the atmosphere. But when spread upon a plate of glass and put in a stove, it becomes gradually so cohesive, that it can be drawn out into threads and becomes at last dry.

Concentrated nitric acid, concentrated sulphuric acid, muriatic, acetic, oxalic, tartaric, succinic and citric acids have no action on eupion. Neither is it acted on by potassium, hydrate of potash, hydrate of lime; nor by solutions of potash, lime, barytes, strontian or ammonia; nor by the alkaline carbonates, the red oxide of lead, the red oxide of mercury, the binoxide of manganese, the black oxide of copper, or the bichromate of potash.

Such are the properties of eupion, so far as they have been investigated. It was named by Reichenbach, from the Greek words εὖ (*bene*) and πιων (*fat*); in consequence of its analogy to fatty matters.

M. Laurent analyzed eupion, which he got from M. Boyveau, but it is obvious that it was not pure, for he says that its boiling point was 336°. Its constituents were

Carbon . .	85·3 or 9·5	atoms
Hydrogen . .	15·1 or 10	atoms
	100·4*	

Hesse analyzed a specimen prepared by distilling hemp oil, and found it composed of

Carbon . .	83·37 or 8·5	atoms
Hydrogen . .	16·37 or 10	atoms
	99·74†	

New researches will be necessary to settle the constituents of eupion with precision.

SECTION VII.—OF CREOSOTE.

This substance was discovered by M. Reichenbach, and the discovery was announced by him at the meeting of the German Scientific Association at Vienna, in 1832.‡ In 1833 M. Reichenbach himself published a detailed account of the process by which he procured it.§ The same year it was analyzed (though not in a state of perfect purity), by M. Ettling, in the laboratory of Professor Liebig.‖

It exists in impure pyrolignous acid, and in the tar obtained by the distillation of wood. As the tar contains it in the greatest quantity, it is most economical to extract it from that substance. This tar is distilled in cast iron retorts till what remains has the consistence of pitch. It is better to stop the distillation too soon than to continue it too long; because the residue is apt to be charred and this would introduce into the distilled liquid empyreumatic substances, of the same nature with those from which it is the object of the distillation to free it. The receiver after the process contains an oil, and a quantity of acidulous water, which last liquid is thrown away.

The oil is distilled anew in a glass retort. We must take care not to continue the distillation to dryness. And the acidulous water which will be found in the receiver along with the oil is to be thrown away.

The oil which first comes over during these two distillations is light; but its density augments as the heat increases. At a certain period of the distillation, this oil begins to sink under the water. We must pay attention to this period. The oil, which swims over the water is poor, in creosote consisting chiefly of eupion and some other substances still lighter, which alter its purity. Hence the oil which swims on the water in the receiver may be thrown away.

The heavy oil has a pale yellow colour; but becomes brown in the air. Its smell is disagreeable. Its taste is acid, caustic, and at

* Ann. de Chim. et de Phys. lxiv. 326.
† Ann. der Pharmacie, xxiii. 247.
‡ Poggendorf's Annalen, xxv. 631.
§ Ibid. xxviii. 125, and xxix. 62.
‖ Ann. de Chim. et de Phys. liii. 325.

once bitter and sweet. This oil is heated, and carbonate of potash is added to it as long as carbonic acid is disengaged. It is then decanted off in order to separate a quantity of acetate of potash, which has formed, and distilled again in a glass retort. The distillation is not continued till the matter in the retort becomes quite dry: and the first products, which swim on the water are thrown away.

The oil is now dissolved in a solution of caustic potash having a specific gravity of 1·12. Much heat is evolved: a portion of eupion mixed with other oils does not dissolve; but swims on the surface. It must be removed. The alkaline liquid is now poured into an open evaporating vessel and raised to the boiling temperature. It absorbs rapidly, a great deal of oxygen from the atmosphere. An oxidable matter contained in the liquid is in a great measure decomposed by this absorption. This causes the whole to assume a brown colour. The liquid is now allowed to cool in the open vessel and dilute sulphuric acid is added to it till the oil separates from the alkali.

This oil is mixed with water containing a little caustic potash and distilled. As water dissolves a little creosote, we must in order to prevent too great a loss, pour back into the retort, from time to time, the water that passes over into the receiver. Though the water is kept boiling briskly, the creosote passes over slowly, because its tension, at 212°, is very feeble. After a certain time, though a good deal of oil still remains in the retort, yet very little passes over though we augment the fire. It is time when this happens to stop the distillation. The residue contains *picamar*, a small quantity of picamar combined with potash, sulphate of potash, a little acetate of potash and a brown coloured matter.

The oil, distilled over, is separated from the water which has passed over along with it. We dissolve it a second time in a solution of caustic potash of the specific gravity 1·12. There remains a notable quantity of light oil, which does not dissolve. It consists as before of eupion mixed with several oily bodies, and is of course separated. The solution is raised to the boiling temperature in an open vessel and allowed to cool slowly. Its colour again becomes brown, though in an inferior degree. Sulphuric acid is added as before, and a slight excess is requisite that the oil itself may absorb a small quantity. The oil is then washed repeatedly with water till all the acid is removed.

This oil is again mixed with water to which no potash is now added; but a little phosphoric acid to remove a small portion of ammonia, which the oil still retains.

The distilled oil is dissolved a third time in caustic potash. No oily residue now remains, and the solution does not become brown when heated and cooled; but acquires merely a slight reddish tint.

In this state creosote is not quite pure, though it may be employed for medicinal purposes. To purify it completely, we should distil it with water without any addition, and then rectify the product of this distillation which is hydrated. There passes first into

the receiver a good deal of water. Its amount diminishes gradually, and at last it ceases to come over altogether, while at the same time a little creosote comes over. These first products must be rejected. We must not begin to collect the creosote till it comes over alone, and till the boiling point rises to 397°. If we rectify the product thus obtained, and cause the vapours to pass over chloride of calcium, we will obtain creosote still more completely deprived of water.

Such was the original process of M. Reichenbach. It has been recently a good deal simplified by M. Hubschmann.* He takes the tar formed during the manufacture of pyrolignous acid, puts it into a large retort along with some grains of sand, in order to increase the number of bubbles that are formed during boiling, and thus diminish its violence. What comes over first, consisting of eupion, acetic acid, &c., is laid aside, but whenever a liquid begins to appear which falls drop by drop into the receiver, and falls to the bottom of the water, the receiver is changed and the product collected. The distillation is continued till the mass begins to froth. The product of the distillation is poured into a vessel with about double its volume of water, to which as much sulphuric acid has been added, as will enable the liquid containing the creosote to swim on the surface. The liquid is slowly raised to the boiling temperature, and kept boiling for some minutes. The whole is now allowed to cool. The colourless liquid which is undermost is abstracted, and the brown oil swimming on the surface rectified in a retort. What comes over is to be treated again as before, with dilute sulphuric acid. It again assumes a brown colour. But after another rectification, and being freed from eupion, it has a straw-yellow colour.

To separate the eupion, the product should be dissolved in a solution of caustic potash, according to Reichenbach's method above described. The light oil which swims is separated, the potash ley heated, and after it has been allowed to cool, the potash is saturated with sulphuric acid, which causes the creosote, of a brown colour, to swim on the surface. This creosote being separated, agitated with water containing some potash, and then distilled in a fresh retort, is almost colourless. But as it becomes brown on exposure to the air, Hubschmann recommends keeping it for some weeks in a cellar in an open bottle, mixing with it a little potash. Being now rectified it may be considered as nearly pure.

Creosote thus obtained, is a colourless transparent liquid, which refracts light very powerfully. Its odour is penetrating, and disagreeable, somewhat analogous to that of smoked meat. Its taste is hot and very caustic. Its specific gravity is 1·037, at the temperature of 68°. It boils at 397°½, and does not congeal when cooled down to —16°½. It burns with flame, emitting at the same time a great deal of smoke. It is a nonconductor of electricity.

With water, at the ordinary temperature of the atmosphere, it forms two combinations: one, a solution of 1·25 parts of creosote in

* Ann. de Chim. et de Phys. lvii. 105.

100 of water, the other, a solution of 10 parts water in 100 of creosote. The aqueous solutions of creosote are neutral. For they have not the property of neutralizing either acids or alkalies.

Concentrated creosote dissolves black oxide of copper, and assumes a chocolate colour. It reduces red oxide of mercury at a boiling temperature, and is at the same time changed into a resin, which contains no creosote.

Nitric acid attacks creosote with energy, while red fumes are emitted. It is coloured by chlorine, bromine, iodine, phosphorus, and sulphur. When it absorbs chlorine it assumes at first a pale-yellow colour, then acquires a deep reddish-yellow tint, while a resin, similar to that from red oxide of mercury, is formed.

When potassium is thrown into creosote, it disappears with the evolution of a gas, and the formation of potash, which combines with, and thickens the creosote. When we distil this mixture, we obtain a portion of the creosote unaltered.

A small quantity of concentrated sulphuric acid, gives creosote a red colour; a larger quantity blackens and thickens it. The sulphuric acid is decomposed, and sulphur disengaged.

Of all the organic acids, it is the acetic which is the best solvent of creosote. These two bodies may be mixed in any proportion.

Creosote forms, without the assistance of heat, two different combinations with potash: the one is an anhydrous liquid having an oily consistence, the other, a hydrous solid, crystallized in scales, having a white colour, and a pearly lustre. All the acids, even the carbonic, separate the creosote unaltered from these combinations. Soda acts precisely in the same way as potash.

Creosote has considerable affinity for hydrates of barytes and lime, forming with them compounds of a dirty white-colour, soluble in water, and which, when dry, constitute a pale rose-coloured powder. Ammonia dissolves creosote without the assistance of heat. This alkali is usually combined with creosote, and is separated from it with difficulty.

Creosote dissolves a great many salts; some cold, others with the assistance of heat. Some are reduced; but the greater number separate in crystals when the solution cools. As examples may be mentioned, acetates of potash, soda, ammonia, lead, and zinc, and chlorides of calcium and tin. It reduces the acetate and nitrate of silver.

Alcohol, ether, bisulphuret of carbon, eupion, naphtha, and acetic ether, may be mixed in all proportions with creosote.

Paraffin has very little tendency to combine with creosote. It does not dissolve in it unless the creosote contains eupion, and the quantity dissolved is proportional to the quantity of eupion present.

Of all organic bodies, the resins and colouring matters dissolve best in creosote. It forms, without the assistance of heat, a reddish-yellow solution with cochineal, a deep-red solution with dragon's blood, a pale-yellow with red saunders, a purple with archil, a yellow with madder, and a golden-yellow with saffron. When placed in

contact with indigo, and assisted by heat, it dissolves its colouring matter, which is precipitated when we add alcohol and water.

It dissolves caoutchouc with great difficulty, when assisted by a boiling temperature; very different in this respect from eupion, which attacks that body with such facility.

When creosote is placed in contact with albumen, it coagulates it immediately. If, into a dilute aqueous solution of albumen, we add a single drop of creosote, white pellicles of coagulated albumen immediately make their appearance.

When fresh *meat* is put into an aqueous solution of creosote, and after remaining half an hour is taken out again, we may expose it to the heat of the sun without any risk of its putrefying. It becomes hard in about eight days, assumes an agreeable odour of good smoked meat, and acquires a reddish-brown colour. Fish may be preserved by the same means. Now, since pyrolignous acid and tar water produce the same effect, there can be no doubt that creosote is the antiputrid principle of these bodies, as well as of smoke.*

Creosote coagulates the albumen of the blood instantly, when the two liquids are concentrated; gradually and slowly if one or other of them be mixed with water. Fibrin is not acted on by this substance.

When a drop of creosote is applied to the tongue it occasions a violent pain. When concentrated creosote is applied to the skin it destroys the epidermis. Insects or fishes die speedily in an aqueous solution of creosote. Plants die also when watered with this solution.

It may replace with advantage, tar, pyrolignous acid, animal oil of Dippel, and empyreumatic water in the practice of medicine. Of late years, it has been employed successfully, both on the continent and in this country, as a cure for toothache occasioned by a carious tooth.† In Germany it is said to have been employed with effect, as a cure for hemorrhages, ulcers, and even cancers. But the trials made of it in these diseases in Great Britain have not been successful. Indeed M. Hubschmann makes the same remark with regard to the use of creosote as a medicine in Germany.‡ The same observation has been made by the medical men who tried it in Paris. When given in too large doses it acts as a violent poison.

Creosote was analyzed by M. Ettling. The specimen examined had been prepared by Reichenbach, who had not been able to free it completely from water. He obtained, as the mean of two analyses,

* It is from this property that Reichenbach imposed the name *creosote* upon this substance. It is derived from κρεας, *flesh*, and σωζειν, *to save*. The term *creasote* would, however, have been more conformable to this etymology than *creosote*.

† In Glasgow it was prepared by Messrs Turnbull and Company; who have long supplied this country with excellent acetic acid from wood, and with pyroxylic spirit.

‡ Ann. de Chim. et de Phys. lvii. 108.

Carbon	75·06 or 6	atoms = 4·5	or per cent.		75·81
Hydrogen	7·78 or $3\frac{1}{2}$	atoms = 0·4375	—	—	7·38
Oxygen	17·16 or 1	atom = 1·0	—	—	16·81
	100·00*	5·9375			100·00

But no conclusion can be drawn from these numbers, as we are ignorant of the atomic weight of creosote; and do not know how much water was present in the specimen subjected to analysis, by M. Ettling.

The *carbolic* acid of Runge, appears to be nothing else than an impure *creosote*.

SECTION VIII.—OF AMPELIN.

This substance was prepared by M. Laurent, from the oil of bituminous slate, which boils between 392° and 536°.†

This oil was agitated repeatedly with concentrated sulphuric acid, and then mixed with a 15th or 20th of its bulk of caustic potash dissolved in water. Being left at rest for 24 hours, it separates into two layers, the undermost of which is more bulky than that of the potash liquid employed. This inferior layer is separated, and shaken with dilute sulphuric acid, which separates an oil, that swims upon the surface. This oil is drawn off by a sucker, introduced into a flask, and agitated with ten times its bulk of water. The ampelin dissolves, and the small portion of oil remaining is thrown away. A few drops of sulphuric acid causes the ampelin to separate and swim on the surface.

It is an oily-looking liquid, soluble in all proportions in water. If we dilute the solution with 40 or 50 times its weight of water, it acts with reagents in the following singular manner:—

Some drops of sulphuric or nitric acid cause the ampelin to separate.

Potash and ammonia render the liquid muddy, but when heated it becomes transparent.

Carbonate of ammonia renders the solution muddy.

Carbonates of potash and soda act in the same way, but heat restores the transparency of the liquid.

Sal ammonica, chloride of sodium, and phosphate of soda, separate the ampelin.

When sal ammonica or common salt is added to a solution of ampelin in potash or soda, the ampeline is separated.

Nitric acid attacks ampelin violently at a boiling heat, and transforms it into a viscid insoluble substance. Some oxalic acid is formed.

When ampelin is distilled, it undergoes decomposition, water and oil pass over, and much charcoal remains in the retort.

SECTION IX.—OF PICAMARE.

This substance was also obtained by M. Reichenbach, from the

* Annalen der Pharmacie, vi. 208.

† Ann. de Chim. et de Phys. lxiv. 326.

tar of wood.* It may be obtained by the following process:—Wood tar is distilled and the products kept separate. Those products which have a specific gravity between 1·080 and 1·095, are poured into eight times their weight of a solution of caustic potash, of the specific gravity 1·15. The two liquids are mixed as rapidly as possible, and then left in a state of rest. There is formed at the surface, a layer of impure eupion containing paraffin. The liquid then becomes transparent, and in 24 hours is filled with shining crystals, in needles or plates. These crystals are dried by pressure between folds of blotting paper. They are then dissolved repeatedly in a boiling solution of potash, till the mother waters become colourless, and the crystals assume the colour of nankin. They are then decomposed by diluted phosphoric acid. The potash combines with the acid, and a limpid, brownish oil separates. This oil is distilled two or three times successively, with water acidulated with a little phosphoric acid. Finally it is cautiously distilled without any addition. In this state it constitutes *picamare*.

It is a limpid transparent liquid, almost colourless, and having the consistence of a thick oil. It has an oily feel. Its smell is weak, but peculiar, and not disagreeable. It has an unsupportably bitter taste, at first giving an impression of heat, and then of cold, somewhat like oil of peppermint.†

Its specific gravity is 1·10, at the temperature of 68°.

Oxygen has no action on it at the ordinary temperature of the atmosphere. It brings red lead to a lower degree of oxidizement. It reduces the red oxide of mercury.

Chlorine, bromine, and iodine attack it and alter it. It dissolves without alteration in sulphuric acid, and decomposition does not take place till the mixture is heated to 302°. Nitric acid destroys it. It dissolves readily in acetic acid. M. Reichenbach is of opinion, that the bitterness of common pyrolignous acid is owing to the presence of picamare.

With potash it forms a crystalline compound, which is almost insoluble in alcohol. Dilute alcohol, when assisted by heat, dissolves a considerable quantity of these crystals, which separate in shining white crystals when the solution cools. When these crystals are not perfectly pure, they assume, by degrees, a brown or blue colour; when very impure, they acquire almost as deep a blue colour as indigo. In these crystals the potash is not neutralized, but retains its alkaline characters. Lime, soda, barytes, and ammonia form also combinations with picamare.

It dissolves in all proportions in alcohol, ether, acetic ether, pyroxylic spirit, and creosote. It does not dissolve paraffiin, asphalt, nor amber. Caoutchouc is dissolved by it with the assistance of heat, but precipitates again when the solution cools.

* Schweigger's Jour. lxvii. Jour de Pharmacie, xx. 362.

† The name given by Reichenbach, is derived from this taste. *In pice amarum*, or *the bitter principle in pitch*.

No attempts have been made to determine the constituents of picamare, by subjecting it to an ultimate analysis.

SECTION X.—OF PITTACALL.

This remarkable substance, which also constitutes an ingredient in wood tar, was described and named by M. Reichenbach about the same time that he gave an account of *picamare*. But there is little doubt that it is the same as a substance of a violet-blue colour, extracted in 1827 from coal tar by MM. Barthe and Laurent.

If to an alcoholic solution of impure *picamare*, or of oil of tar deprived of its acid, we add some drops of barytes water, the liquid immediately assumes a fine blue colour, which, in about five minutes, passes into indigo blue. This phenomenon is owing to the presence of *pittacall* in the solution.

When this substance is precipitated in flocks from its solution, or when it is obtained by evaporation, it constitutes a dark blue, solid, brittle substance, like indigo. Like that pigment, when rubbed, it assumes a copper colour, passing, according to its degree of purity, into golden or brass yellow. The golden lustre predominates so much, that we cannot obtain pittacall free from it; and all substances over which it is spread appear as if they were gilded.*

Pittacall is without smell, is tasteless, and not volatile. At a high temperature it is charred, without giving out the odour of ammonia.

It is insoluble in water; but is suspended in that liquid in a state of tenuity, so great, that it passes through filters and gives a blue colour to the liquid.

It is not altered by exposure to air or light.

It dissolves in diluted sulphuric acid, and in muriatic acid, without the assistance of heat. Nitric acid decomposes it. Acetic acid dissolves it in great abundance; the acid solution is aurora-red; but it resumes its blue colour when an excess of alkali is added to the liquid. According to Reichenbach, it is a reagent for detecting acids and alkalies still more delicate than litmus.

It is insoluble in alcohol, ether, and eupion. With acetate of lead, protochloride of tin, ammoniasulphate of copper, acetate of alumina, it strikes a fine blue colour, with a tint of violet.

No doubt pittacall, if it could be procured at a sufficiently cheap rate, might be employed as a pigment.

SECTION XI.—OF CAPNOMORE.

This substance was discovered by Reichenbach, still more lately than the preceding five, and was so named by him (from *καπνος*, *smoke*, and *μοιρα*, *a part*), because it exists in the smoke of organic bodies.†

* Hence the name *pittacall*, from *πιττα*, *pitch*, and *καλλος*, *beautiful*. So that the name signifies, literally, *beautiful pitch*.

† Jour. de Chim. Medic. i. 195, and Records of General Science, ii. 79. Jour. de Pharmacie, xxi. 245.

It occurs along with creosote, picamare, and pittacall, in the heavy oil of tar. On digesting that oil, deprived of acetic acid, by carbonate of potash, with a solution of potash, of the specific gravity 1·20, we obtain a solution. What does not dissolve after a second digestion with potash, may be thrown away. The alkaline liquor is put on the fire in an open vessel, heated slowly, and allowed to boil for a short time. It is then allowed to cool slowly, and decomposed by dilute sulphuric acid added in slight excess. By this addition, a great quantity of dark-brown oil is disengaged. It is put into a retort along with a little potash, to render it alkaline, and distilled, but not to dryness. The product of the distillation is a transparent pale oil. It is dissolved in a solution of potash, of the specific gravity, 1·16, and what does not dissolve is thrown away. It is heated, as before, to the boiling point, allowed to cool, mixed with dilute sulphuric acid, to separate the oil; saturated with potash, and distilled anew. These processes are repeated several times successively, diminishing every time the concentration of the potash solution to 1·12, 1·08, 1·05.

When the oil is sufficiently pure, it dissolves without residue in sulphuric acid, in which eupion is insoluble. It is mixed with water, allowed to cool, saturated with ammonia, and distilled in a retort. The first portions are rejected; then water comes over, and at last the capnomore, in the form of an oil.

When pure, capnomore is a transparent colourless fluid, having the smell of rum or of punch. At first it appears to have no taste, but it gradually becomes acrid. It refracts light almost as powerfully as creosote.

Its specific gravity, at 68°, is 0·9775. It boils at 365°, under a pressure of 28·25 inches. It does not congeal at —6°. It may be completely distilled over, without leaving any residue. It is a non-conductor of electricity.

It is insoluble in water and in solution of potash, but dissolves in alcohol, ether, and eupion. It has the property of dissolving caoutchouc, especially when heated, and is the only ingredient in tar that does so. According to Reichenbach, the presence of capnomore in coal naphtha, is the cause of the solvent action of that liquid on caoutchouc. But this opinion could not be adopted, unless it could be shown, that capnomore is likewise an ingredient in oil of turpentine.

With the vegetable bases it acts as an acid, and with sulphuric acid and the salts, as a base. It does not unite with the other bases. A combination, indeed, seems to take place, but it is decomposed by water.

Capnomore is distinguished from creosote and picamare by its taste, its insolubility in the alkalies, and in acetic acid, and by the facility with which it dissolves caoutchouc. It differs from eupion by its specific gravity and boiling point, by the smoke which it emits when burning, by its solubility in sulphuric acid, its decomposition by nitric acid, its solubility in carbozotic acid, and its capacity of combining with the vegetable bases.

No attempts have hitherto been made to subject capnomore to an ultimate analysis. The characters above stated are sufficient to show, that carbon and hydrogen are its principal constituents. No phenomenon yet known indicates the presence of azote as a constituent. But its being decomposable by nitric acid, rather favours the notion, that oxygen enters as an essential ingredient into its composition.

SECTION XII.—OF CEDRIRET.

This substance has been lately discovered by Reichenbach. The only account of it which I have seen, is in Berzelius's *Jahr-Bericht*, for 1835, p. 408.

Cedriret may be prepared by the following method :—

The rectified empyreumatic oil, obtained by distilling the tar of beech wood, was, by carbonate of potash, freed from acetic acid, and afterwards treated with a concentrated ley of caustic potash. The alkaline solution was freed from the insoluble portion of the oil, (eupion, capnomore, and mesite,) and the potash saturated with acetic acid. This occasioned the separation of a portion of the dissolved oil, while another portion remained in combination with the acetate of potash, from which it was separated by distillation. When about a third part of it had come over, the receiver was changed, and it was tried whether a drop of the oil, distilling over, when let fall into persulphate of iron, occasioned a red precipitate. As soon as this precipitate began to be formed, the oil that distilled over was collected.

It had the property of striking a red colour with persulphate of iron or chromotartrate of potash, and after an interval of about five minutes, a precipitate of red crystalline needles fell. This precipitate fell slowly, and left the liquid colourless. All substances which easily part with oxygen, produced a similar phenomenon. Even the oxygen of the atmosphere rendered the liquid red. These red crystals were called *Cedriret* by Reichenbach, from *cedrium*, an old name for the sour water of *tar burners*, and *rete*, a *net*, because crystals lie upon the filter, entangled in each other like a net.

Cedriret possesses the following properties :—It crystallizes in fine red needles, which take fire, burn with flame, and disappear without leaving any residuum. It does not melt, but when heated is easily decomposed, and if the temperature be raised still higher, it is charred. Sulphuric acid, free from nitric acid, dissolves it with an indigo-blue colour, which, when heat is applied, or when the acid is diluted, becomes yellowish-brown. Dilute nitric acid has no action on cedriret ; but concentrated acid decomposes it entirely.

Acetic acid, of the specific gravity 1·07, dissolves a little of it, which is not separated when the acid is saturated with ammonia. It is insoluble in bisulphuret of carbon, water, alcohol, ethers, oil of turpentine, eupion, picamare, capnomore, petroleum, oil of almonds, and fused paraffin. But it dissolves, cold, in creosote, with a purple colour, and from this solution it may be precipitated in crystals

by alcohol. The solution is decomposed both by the solar rays and by heat. The cedriret is destroyed, and assumes a yellow colour.

Reichenbach is of opinion, that cedriret, and its solution in liquids containing creosote, and its easy decompositions, will enable us to account for the numerous changes of colour which are observed in pyrolignic acid and tar.

SECTION XIII.—OF NAPHTHALIN.

An account of the mode of obtaining naphthalin and its principal characters, has been given in the *Chemistry of Unorganized Bodies* (vol. i. p. 205). My object here, will be to state the additional facts respecting this interesting substance, which have been determined since the year 1831, when that account was drawn up.

Reichenbach has endeavoured to prove that naphthalin does not exist ready formed in coal tar; but that it is formed when the oil existing in this tar is exposed to a high temperature.* But M. Laurent distilled a quantity of tar previously deprived of its water, by exposing it to heat in an open vessel. The oil which came over first, and before the heat was very much elevated, being exposed to a cold of zero, by plunging it into a freezing mixture of snow and salt, abundance of crystals of naphthalin were deposited. This process does not always succeed; but if a current of chlorine gas be passed through this oil, it darkens in colour, giving out muriatic acid, and at last becomes black. If this oil be agitated with water acidulated with muriatic acid, and then enough of ammonia added to neutralize the acid, a white flocky matter falls, which gradually concretes into greenish globules. The odour of this substance is so penetrating, that if we simply touch it with the point of a finger, we retain a perceptible smell of it for four or five days. Laurent distilled over this altered oil, and divided the product into two portions. The first was limpid, very fluid, exhaled acid vapours, and was not altered by exposure to the air. The second was yellow, oily, and similar to that obtained in the distillation of tar. Both of these liquids when cooled down to zero (indeed, even as high as 41°), deposited abundance of crystals of naphthalin. The quantity, indeed, is so great, that M. Laurent informs us that, by this process, naphthalin could be obtained at a low price, if it were to be applied to any useful purpose.†

Naphthalin crystallizes in rhomboidal plates with angles of 122° and 78°.‡

Chlorine and bromine act with considerable violence on naphthalin; heat is disengaged, and muriatic acid and hydrobromic acids formed. It is not altered by iodine. When the two bodies are melted together, they separate during the cooling. The same remark applies to phosphorus, sulphur, chloride of sulphur, and bisulphuret of carbon. Potassium may be melted in naphthalin without alteration.

* Ann. de Chim. et de Phys. xlix. 36. † Ibid. xlix. 214.

‡ Laurent, ibid. p. 218.

Dumas found the melting point of naphthalin 174°, which accords with my previous experiment. Its boiling point, he says, is 413°½. Dr Kid had previously found it 410°. The specific gravity of its vapour, according to Dumas, is 4·528.

Naphthalin was subjected to analysis by Faraday, Oppermann, and Laurent. The following table shows the results obtained:—

	Faraday.*	Oppermann.†	Laurent.‡	Mean.
Carbon .	94·07	93·24	93·9	93·74
Hydrogen .	5·93	6·20	6·1	6·26
	100·00	99·44	100·0	100

Now, the number of atoms which correspond best with these proportions, and with the specific gravity of the vapour of naphhalin, is

10 atoms carbon	= 7·5	or per cent. 93·75
4 atoms hydrogen	= 0·5	— — 6·25
	8	100

The specific gravity of carbon vapour being 0·4166, and that of hydrogen 0·0694, it follows that

10 atoms of carbon weigh .	4·1666
4 atoms of hydrogen . .	0·2777
	4·4444

MM. Wöhler and Liebig have shown that 13·92 parts of sulphuric acid are saturated by 45·58 parts of naphthalin. According to this experiment, 16·372 parts of naphthalin combine with 5 acid. Hence it is probable that 2 atoms naphthalin combine with 1 atom of sulphuric acid.

When a current of chlorine gas is passed over naphthalin at the ordinary temperature of the atmosphere, the naphthalin melts, and if the disengagement of chlorine be rapid a portion is volatilized, which condenses in the form of a new product on the surrounding bodies. At the same time vapours of muriatic acid are exhaled. When the greatest part of the naphthalin has been acted on, the liquid thickens gradually, a white granular matter is deposited; at last, the whole assumes a solid form, similar in appearance to frozen olive oil. If the whole naphthalin has not been acted on, we must apply a gentle heat to liquefy this solid product, and continue the current of chlorine till saturation takes place. When the action is at an end we find two new compounds; the one solid, white, and granular; the other oily, having a light-yellow colour, and retaining in solution a certain quantity of the preceding solid.

M. Laurent, to whom we are indebted for the investigation of these two chlorides of naphthalin,§ purified the solid chloride in the

* Phil. Trans. 1826. 161.
† Ann. de Chim. et de Phys. xlix. 43. ‡ Ibid. p. 221.
§ Ann. de Chim. et de Phys. lii. 275.

following manner :—He introduced it into a glass tube shut at one end, and poured over it about five or six times its volume of ether, and agitated the whole rapidly. The ether dissolves with facility the oily chloride, while it scarcely acts on the solid chloride, which was deposited speedily when the tube was left at rest. This ether was poured off, and a new portion introduced, and agitated as before. This process was repeated three or four times, and finally the whole was thrown on a filter, the solid chloride was washed with a little ether, and finally exposed to pressure between folds of filtering paper.

If we now dry or melt this chloride to get rid of any adhering ether, it is perfectly pure.

It is much more difficult to obtain the oily chloride free from the solid chloride of naphthalin. M. Laurent adopted the following method :—

The ethereal liquids employed in washing the solid chloride were distilled in a retort, taking care to proceed no farther than to draw off the greatest part of the ether. The residue was exposed to a cold of zero, by means of a freezing mixture of snow and salt. A long exposure to this degree of cold is necessary, in order to cause the deposition of the solid chloride. Sometimes none of it is deposited after an hour at zero, though it crystallizes when left two days in a temperature of 41°. After the deposition of the solid portion, the oily chloride was drawn off by a sucker, and the ether driven off from it by means of heat.

1. *Solid chloride of naphthalin.* This chloride is obtained sometimes in the state of a white crystalline powder, and sometimes in transparent rhomboidal plates, having a glassy lustre. To procure it under this last form, we must dissolve it in boiling ether. When the liquid cools, the chlorine is deposited in crystals. The best way of obtaining the ethereal solution, is to put the chloride, with the ether, into a strong globular glass vessel, furnished with a ground stopper, which is to be tied down. The vessel is placed on the sand-bath, and heated some degrees above the boiling point of ether. When the chloride has dissolved, the whole is allowed to cool slowly on the sand-bath. By this means fine crystals are obtained. They are rhomboidal plates, with angles of about 75° and 105°. These crystals are very brittle, and easily reduced to powder.

This chloride melts, when heated, to 320°. On cooling it concretes into a crystalline mass. At a higher temperature it boils, and undergoes decomposition. Vapours of muriatic acid are disengaged, and a new product is obtained, which is fusible and incrystallizable, while at the bottom of the retort there remains a quantity of frothy charcoal. When heated in a glass tube, open at both ends, it is volatilized without decomposition.

It is insoluble in water. Boiling alcohol dissolves a very minute quantity of it, which is deposited again almost entirely when the liquid cools. It is more soluble in ether, especially when assisted by heat. It has a strong and peculiar smell. It is not altered by

exposure to the air. When melted upon paper and then kindled, it burns with a thick flame, green on the edges, and gives out a great deal of smoke; by itself it will not burn, not even when in the state of vapour.

Chlorine, bromine, and iodine, have no action on it. Potassium, at the ordinary temperature, or when slightly heated, decomposes it with a slight explosion and the production of light. Chloride of potassium is formed, and a great deal of charcoal deposited. If the experiment be made in a glass tube, a gas is disengaged, which burns with a green flame.

Sulphuric acid while cold, does not alter it; but when long boiled on it decomposition takes place. Nitric acid does not act upon it, unless when kept at a boiling temperature. It then very slowly changes it into small yellow crystals.

Muriatic acid and ammonia have no action on it. Potash, while cold, does not seem to alter it. But when boiled upon it a new crystallizable compound is formed, and the potash is changed into chloride of potassium.

It was very carefully analyzed by M. Laurent and by Dumas, who obtained

	Laurent.	Dumas.
Carbon .	44·51	44·69
Hydrogen .	2·49	3·12
Chlorine .	53·00	52·19
	100·00*	100†

The numbers of Dumas lead to the conclusion that the chloride is composed of

10 atoms carbon . . .	7·5
4 atoms hydrogen . . .	0·5
2 atoms chlorine . . .	9·0
	17

Hence, it would appear to be a compound of 2 atoms chlorine and 1 atom of naphthalin. But the evolution of muriatic acid during its formation, renders this opinion unlikely. Laurent, who was at great pains in determining the quantity of hydrogen, obtained a result, which corresponds with

10 atoms carbon	= 7·5	or per cent.	44·33
$3\frac{1}{3}$ atoms hydrogen	= 0·416	— —	2·46
2 atoms chlorine	= 9	— —	53·21
	16·916		100·00

The probability is, that the true composition is

10 atoms carbon	= 7·5	or per cent.	44·44
3 atoms hydrogen	= 0·375	— —	2·22
2 atoms chlorine	= 9·0	— —	53·34
	16·875		100·00

* Ann. de Chim. et de Phys. lii. 280. † Ibid. l. 185.

For these numbers do not deviate farther from the results of Laurent, than the amount of the unavoidable errors to which such delicate experiments are liable. But, if these atomic constituents be admitted, it is not naphthalin in combination with chlorine, but a new compound, composed of 10 atoms carbon, and 3 atoms hydrogen. This new compound approaches pretty closely to the constitution of idrialin, as will appear in a subsequent Section.

2. *Oily chloride of naphthalin.* This chloride, as it was obtained by M. Laurent, is an oily liquid, having a light-yellow colour, heavier than water, and distinguished by a smell similar to that of the solid chloride. It is insoluble in water, but very soluble in alcohol. Ether combines with it in all proportions.

It seems to be capable of being distilled over without decomposition. It does not burn by itself when heated in an open spoon; but it burns with a green flame when spread upon paper or wood, giving out at the same time a good deal of smoke.

Nitric acid converts it into a yellow viscid matter. Potassium, even when assisted by a boiling temperature, does not appear to alter it. Potash is equally without action.

Laurent subjected to an ultimate analysis a quantity of this liquid chloride, containing in solution a certain quantity of solid chloride, from which he was unable to free it. The result was

Carbon	54·9 or 90	atoms =	67·5
Hydrogen	3·3 or 32·5	atoms =	4·0625
Chlorine	41·8 or 11·5	atoms =	51·75
	100·0*		123·3125

But M. Laurent considers the true constituents to be

90 atoms carbon	= 67·5	or per cent.	55·66
34 atoms hydrogen	= 4·25	— —	3·51
11 atoms chlorine	= 49·5	— —	40·83
	121·25		100·00

If these numbers be not considered as deviating too far from the results of the analysis, it is obvious that we may resolve them into

$$7\,(C^{10}\,H^{4} + Ch) + 2\,(C^{10}\,H^{3} + Ch^{2})$$

But $C^{10}\,H^{3} + Ch^{2}$ represents an atom of the solid chloride of naphthalin. $C^{10}\,H^{4} + Ch$ must represent the constitution of an integrant particle of the oily chloride. And the substance analyzed was obviously a mixture of

7 atoms oily chloride of naphthalin
2 atoms solid chloride of naphthalin.

If this ingenious reasoning be admitted, then it follows that the oily chloride is a compound of 1 atom of naphthalin, and 1 atom chlorine.

If the oily chloride be a compound of

* Ann. de Chim. et de Phys. lii. 283.

10 atoms carbon . . .	= 7·5
4 atoms hydrogen . .	= 0·5
1 atom chlorine . . .	= 4·5
	12·5

then its atomic weight will be 12·5, and it will be composed, per cent., of

Carbon	60
Hydrogen	4
Chlorine	36
	100

3. *Nitronaphthalase.* This compound was discovered in 1835, by M. Laurent.*

When nitric acid and naphthalin are left in contact at the common temperature of the atmosphere, no action takes place. But if we boil the acid, red vapours are emitted, and an oily layer collects on the surface, which, in about 20 minutes, quite changes its nature. We obtain a yellow oil, which becomes solid very slowly after cooling, forming a crystalline mass in yellow needles. This matter is composed of two products, very soluble in alcohol and ether: one, solid, which is *nitronaphthalase;* the other, a liquid which is partly separated by pressure between the folds of blotting paper. To separate the whole of the oil, the impure nitronaphthalase is dissolved in boiling alcohol in a capsule. On cooling, it deposits first, drops of oil. These are separated by a sucker. They contain a great deal of nitronaphthalase. The alcohol being left at rest for 12 hours deposits fine crystals of nitronaphthalase. It is purified still farther, by one or two additional crystallizations.

Nitronaphthalase may be prepared in another way, by means of hyponitrous acid. To the beak of the retort containing the nitrate of lead, we adapt a large tube, bent like U. In the bend of this tube we put naphthalin, and then apply heat to the retort. The hyponitrous acid disengaged acts cold with great energy on the naphthalin. We obtain here also nitronaphthalase, together with an oil. It is to be purified, as before directed.

Nitronaphthalase crystallizes in long square prisms, terminated by very acute pyramids. Its colour is sulphur-yellow. It melts at 109°½; and when it becomes solid, the thermometer suddenly rises to 129°. It may be sublimed without decomposition. The vapour is deposited on cold bodies in small needles. When we operate on a large quantity, or raise the heat suddenly, it is decomposed at once with the disengagement of a red light, and leaving behind it a great quantity of charcoal. When heated on platinum foil it burns with a red flame and much smoke.

It is neutral, insoluble in water, but very soluble in alcohol and ether. Chlorine decomposes it with the assistance of heat. We ob-

* Ann. de Chim. et de Phys. lix. 376.

tain an orange-red oil, which concretes on cooling. It possesses the characters and composition of chloronaphthalase. Bromine, in like manner, produces bromonaphthalase. Iodine has no action on it.

When heated with sulphur it melts, then dissolves the sulphur; and if the solution be heated it boils, sulphurous acid is disengaged, and a green matter, not homogeneous, is obtained. One portion of it is soluble in ether, to which it gives a green colour. Potassium suddenly decomposes nitronaphthalase at the temperature of 109°½. Light is disengaged, and charcoal evolved.

Muriatic acid has no action on it. Nitric acid converts it into nitronaphthalase. Concentrated sulphuric acid dissolves it without alteration, and water throws it down. At a boiling heat the acid becomes brown, and then water occasions no precipitate. Caustic potash ley produces little change upon it, even at a boiling temperature. But in an alcoholic solution of potash it becomes red, and concentrated sulphuric acid changes it to green or bluish-green.

M. Laurent subjected it to an ultimate analysis, and obtained

Carbon	69·86	or 20 atoms	= 15	or per cent.		69·36
Hydrogen	4·06	or 7 atoms	= 0·875	—	—	4·04
Azote	8·5	or 1 atom	= 1·75	—	—	8·19
Oxygen	17·56	or 4 atoms	= 4·00	—	—	18·50
	100		21·625			100·00*

It is easy to see now what happens when nitric acid acts on naphthalin.

2 atoms of naphthalin are	C^{20} H^{8}	
1 atom nitric acid .		Az O^{5}
	C^{20} H^{8}	Az O^{5}
1 atom nitronaphthalase	C^{20} H^{7}	Az O^{4}
Difference . .	H	O

So that 1 atom of the nitric acid loses an atom of oxygen, while the naphthalin loses an atom of hydrogen, both together being converted into water.

4. *Nitronaphthalese.* This substance was also described by M. Laurent, in 1835.†

When nitronaphthalase is boiled for a long time in nitric acid, we obtain a new crystalline substance, which Laurent has called *nitronaphthalese.* But this process is tedious. It is better to boil the acid with nitronaphthalase, while under the form of a layer of

* M. Laurent does not furnish us with the data on which his numbers are founded, but only the result of his analysis per cent. This prevented me from correcting his numbers; and hence the want of coincidence between the analysis and the formula, which would have nearly disappeared, had the requisite corrections been applied.

† Ann. de Chim. et de Phys. lix. 381.

oil. We evaporate rapidly in a flask. If we watch till the oil and acid become nearly of the same bulk, and then stop the process, the whole concretes into a solid mass on cooling. Wash it with hot water, and then with hot alcohol, in which it is nearly insoluble. It is nitronaphthalese under the form of a light powder composed of minute needles.

It is insoluble in water, very soluble in boiling alcohol, and slightly so in ether. It melts at 365°. When strongly heated it sublimes in small needles without decomposition. But when a considerable quantity is heated at once, it is suddenly decomposed with a violent disengagement of gas, while much charcoal is deposited. A good deal of light is evolved.

Nitric and muriatic acid have no action on it. Concentrated sulphuric acid dissolves it with the assistance of heat. On cooling the nitronaphthalese is deposited in needles. It is also precipitated by water. When melted with sulphur, sulphurous acid is disengaged, and sulphuretted hydrogen. Concentrated boiling potash ley alters it but little; the solution becomes brown and some ammonia is disengaged.

Laurent subjected it to analysis, and states its composition to be

Carbon	54·6 or	20 atoms =	15	or per cent.	55·05
Hydrogen	2·9 or	6 atoms =	0·75	— —	2·75
Azote	12·7 or	2 atoms =	3·5	— —	12·85
Oxygen	29·8 or	8 atoms =	8·0	— —	29·35
	100·0		27·25		100

We see from this that the nitric acid takes away another atom of hydrogen, and adds an additional atom of nitrous acid, or Az O^4 to the nitronaphthalase.

5. *Naphthalase.* This substance was also discovered and described by M. Laurent, in 1835.*

If we mix nitronaphthalase with 8 or 10 times its weight of lime slightly moistened in a small retort, so that it shall be full to the neck, and apply heat, a brown oil is disengaged, containing much naphthalin, together with ammonia, and nitronaphthalase undecomposed, and there is condensed in the neck of the retort a thick oil, which becomes solid on cooling. The lime is blackened by the deposition of charcoal. We must heat very gently, otherwise the whole takes fire, and very little of the products just mentioned are obtained. To obtain the solid matter in the neck of the retort, we cut it off as near the throat as possible, and wash the solid matter with ether, which dissolves the foreign matter. A yellow powder remains which is naphthalase.

It is insoluble in water and alcohol, and scarcely soluble in ether. It does not melt at 482°, but at that temperature it begins to sublime. If the heat be increased, it melts and then boils. Its vapour is yellow, and it condenses in scales or long yellow needles.

* Ann. de Chim. et de Phys. lix. 383.

When the smallest quantity of it is dissolved in cold sulphuric acid, the whole liquid assumes a very strong and fine violet-blue colour. Water throws down the naphthalase unaltered, and it becomes again blue by the contact of concentrated sulphuric acid. Idrialin also strikes a blue with sulphuric acid, but only when heated, and nitric acid destroys this power in idrialin, but not in naphthalase. It was analyzed by M. Laurent, who obtained

Carbon	87·0 or 20 atoms	=	15	or per cent.	88·89
Hydrogen	4·8 or 7 atoms	=	0·875	— —	5·18
Oxygen	8·2 or 1 atom	=	1	— —	5·93
	100·0		16·875		100

But this formula deviates too far from the analysis to be adopted. The analysis leads to the formula

14	atoms carbon	= 10·5	or per cent.	87·04
$4\frac{1}{2}$	atoms hydrogen	= 0·5625	— —	4·67
1	atom oxygen	= 1	— —	8·29
		12·0625		100·00

But as the analysis was only once made, no great reliance can be placed on it.

Laurent considers it as nitronaphthalase, minus an atom of hyponitrous acid. But we have no evidence that it does not contain azote.

SECTION XIV.—OF PARANAPHTHALIN.

This substance was discovered by M. Dumas in 1832, in coal tar, and named by him *paranaphthalin*, because from his experiments it appears in its composition to be perfectly identical with naphthalin.*

When we distil coal tar, the products obtained may be divided into four different sets. The first product is an oily substance, which furnishes a good deal of pure naphthalin. The second product is also oily; but it yields both naphthalin and paranaphthalin, which may be separated from each other by means of alcohol. The third product is viscid; it contains, so to speak, only paranaphtalin; but it is accompanied by a viscid substance, which renders its purification very difficult. The fourth product is distinguished from the third, by containing the reddish-yellow or orange substance, which appears at the end of all similar distillations.

To obtain paranaphthalin from the second of these products, we have only to expose it to the temperature of zero, by means of a freezing mixture of snow and salt. The paranaphthalin is deposited in crystalline grains. Let it be thrown upon a cloth and pressed, in order to separate the liquid portion. If we now digest it in alcohol, the naphthalin and other substances which it contains are dissolved, and the paranaphthalin remains in a state of con-

* Ann. de Chim. et de Phys. l. 187.

siderable purity. If we distil it over two or three times successively, it will be rendered quite pure.

The third and fourth products of the distillation of coal tar, must be treated somewhat differently. Let the whole of them be dissolved in the smallest possible quantity of oil of turpentine, and let the solution be cooled down to zero. The paranaphthalin crystallizes in hard grains. The whole is thrown on a cloth through which the liquid is pressed. After being washed in alcohol, it is purified as before by repeated distillations.

Paranaphthalin thus purified melts at 356°, while naphthalin melts at 174°. Its boiling temperature exceeds 572°. Yet it may be distilled over unaltered; or at least the quantity of charcoal which it leaves, diminishes at each distillation, and becomes at last almost insensible. It is easily sublimed before fusion. It condenses in plates, the figure of which has not been determined.

It is insoluble in water, and scarcely soluble in alcohol, even at a boiling temperature. What dissolves, again precipitates in flocks when the solution cools. This distinguishes it from naphthalin, which dissolves abundantly in hot alcohol, and precipitates in crystals when the solution cools. Ether acts like alcohol. The best solvent is oil of turpentine.

Concentrated sulphuric acid dissolves paranaphthalin by the assistance of heat. The solution has a dirty-green colour, owing probably to the presence of a little of the orange-coloured matter which always accompanies it.

Nitric acid attacks it, nitrous vapours are exhaled, and a substance remains, which sublimes, at least partially, in needles.

Dumas subjected paranaphthalin to an ultimate analysis. The mean of three analyses gave

Carbon	92·3	or per cent.	93·85
Hydrogen	6·05	— —	6·15
	98·35*		100·00

This is obviously the same with the composition of naphthalin or

10 carbon	7·5
4 hydrogen	0·5
	8·0

Dumas determined the density of the vapour of paranaphthalin, by heating it to the temperature of 842°, determined by an air thermometer. The specific gravity was 6·741, supposing the temperature reduced to 32°. Now

15 volumes carbon weigh	6·25
6 volumes hydrogen	0·4166
	6·6666

It is clear from this, that a volume of vapour of paranaphthalin is

* Ann. de Chim. et de Phys. l. 190.

composed of 15 volumes of carbon vapour, and 6 volumes of hydrogen gas. The number of atoms in a volume of paranaphthalin vapour is to that of naphthalin vapour as 3 to 2. So that, though the ratio of the elementary constituents is the same, yet the number of atoms requisite to constitute an integrant particle is different in each. Thus it appears, that various multiples of 10 carbon + 4 hydrogen, may enter into combination as well as of 1 carbon + 1 hydrogen.

M. Laurent, by treating paranaphthalin with nitric acid and subliming, obtained a substance crystallized in needles, to which he has given the name of *paranaphthalese*.* This substance is white, insipid, destitute of smell, and may be volatilized in small quantities without decomposition. When heated on platinum foil it burns with a fuliginous flame and leaves a residue. It is neutral and insoluble in water and alcohol, and scarcely soluble in ether. It is not altered when heated with muriatic acid, potash or lime. Boiling naphtha dissolves a little of it. Hot concentrated sulphuric acid is its best solvent. Nitric acid dissolves a little of it. M. Laurent found its constituents

Carbon	80·8 or 15 atoms	= 10·5	or per cent.		79·24
Hydrogen	3·6 or 6 atoms	= 0·75	—	—	5·67
Oxygen	15·6 or 2 atoms	= 2	—	—	15·09
		13·25			100

Making it to differ from paranaphthalin, by the addition of 2 atoms of oxygen. But if this formula be correct, the substance analyzed must have been very impure.

SECTION XV.—OF IDRIALIN.

This remarkable substance, which occurs in the mercurial mine of Idria, in that variety of ore called on the spot *branderz*, was first made known to chemists in 1814, by M. Payssé, in his statistical notice of the Mercurial mine of Idria.† When branderz is distilled, idrialin comes over in brilliant plates, light and micaceous, melting like wax when exposed to a gentle heat, and burning with the exhalation of a balsamic odour.

No notice was taken of this account of idrialin, by M. Payssé, either by mineralogists or chemists. No specimen of *branderz* is to be found in any mineral collection that I have seen; nor am I aware of any allusion to it either in mineralogical or chemical works, till it drew the attention of M. Dumas in 1832. He could find no specimen of *branderz* in the rich mineral cabinet belonging to the *Ecole des Mines* at Paris. In the mineral collection of the *Jardin du Roi*, there was only a small fragment; but luckily some pieces of it existed in the collection of the *Ecole Polytechnique* which enabled him to make some experiments.‡

The pieces of branderz which he procured, resembled common

* Ann. de Chim. et de Phys. lx. 220. † Ann. de Chim. xci. 201.
‡ Ann. de Chim. et de Phys. l. 193.

coal very much, excepting that they had a brown colour. One of them contained no mercury, and the two others only traces of that metal. When heated gently in a glass tube open at both ends they melted, and allowed a great quantity of crystalline powder to exhale. This substance is what Dumas has distinguished by the name of *idrialin*.

To obtain idrialin, considerable precautions are requisite. For, unlike napththalin and paranaphthalin, it is not volatile without decomposition. Dumas procured it in the following manner:—

The mineral broken into fragments was put into a tubulated retort, whose neck, almost vertical, plunged into a long and narrow glass cylinder. A current of carbonic acid gas was made to pass through the retort. Heat being cautiously applied, the mineral melted and boiled, giving out first mercurial vapours, and then idrialin in abundance. The process was continued till the retort melted, and the evolution of idrialin went on to the end without the least trace of water, bitumen, or oil.

To free the idrialin from the mercury which was disseminated through it, the whole was digested in oil of turpentine at a boiling temperature. When the solution cools, the idrialin is deposited so rapidly that the whole mixture becomes almost immediately solid. It is separated from the oil of turpentine by filtration and pressure between folds of blotting paper.

Idrialin is volatile, but it does not rise without being altered in its nature. When we attempt to distil it, we lose at least $\frac{9}{10}$ths of the whole, even when we operate *in vacuo*, or in a current of carbonic acid gas. Idrialin may be fused, but at a temperature so high that we can scarcely fuse it without altering its nature.

It is not sensibly soluble in water even at the boiling temperature. It is scarcely soluble in boiling alcohol or ether. The only known solvent of it is oil of turpentine. The oil must be boiling hot, and the idrialin precipitates whenever the solution cools.

When sulphuric acid is heated in contact with idrialin, that substance is dissolved and the solution assumes a fine blue colour like that of sulphate of indigo.

M. Dumas subjected idrialin to an ultimate analysis, and ascertained that its only constituents were carbon and hydrogen. He found the constituents

Carbon	94·8 or 3 atoms	= 2·25	or per cent.	94·73
Hydrogen	5·2 or 1 atom	= 0·125	— —	5·27
	100·0	2·375		100·00

As we neither know the atomic weight of idrialin, nor the specific gravity of its vapour, we can draw no conclusion from this analysis respecting the number of atoms which enters into its composition. But it is obvious that this number must be a multiple by a whole number of 3 atoms carbon + 1 atom hydrogen.

M. Dumas has rendered it exceedingly probable that idrialin exists ready formed in *branderz*. When oil of turpentine is boiled with

the powdered mineral, it deposits, on cooling, some crystals of idrialin. Even alcohol at a boiling temperature dissolves from the mineral a little idrialin. For if we filter and evaporate this alcohol it deposits some plates having a pearly lustre. If these plates be washed in cold water and then digested in hot sulphuric acid, the liquid immediately assumes the fine blue colour which characterizes idrialin.

It is said that *branderz* is no longer to be found in the mine of Idria. If this be so, it will not be in the power of chemists to subject idrialin to further experiments.

SECTION XVI.—OF EBLANIN.*

This name has been given by Mr Scanlan, to a substance discovered by him in *raw* pyroxylic spirit. Unless I am mistaken, he gave an account of the mode of obtaining it, and described its most remarkable properties at the meeting of the *British Scientific Association* at Bristol, in 1836. And an account of it together with an analysis by Drs Gregory and Apjohn, was published in *Liebig's Annalen der Pharmacie*, for 1837.†

To obtain it, raw pyroxylic spirit is distilled over slacked lime. The dry residue is a mixture of lime, acetate of lime, and *eblanin*. The lime is taken up by dilute muriatic acid, and the residue is digested in spirit of wine. From this solution the eblanin is deposited in long needles or prisms, having the colour of carbazotate of potash. It has no smell. It is insoluble in water and in the alkalies, but soluble in alcohol, ether, and concentrated acetic acid; and is thrown down in flocks from alcohol, and acetic acid, by the addition of water.

It sublimes when heated to 273°, and does not melt till it is raised to the temperature of 291°. Concentrated sulphuric acid dissolves it and assumes a reddish-blue colour. But the solution soon becomes brown, and a great quantity of brownish flocks precipitate. Concentrated muriatic acid dissolves it slowly, assuming a beautiful and intense purple colour, like the solution of hypermanganate of potash. This colour gradually disappears while charcoal is deposited. Nitric acid dissolves it. When the fuming acid is used, hyponitrous acid is disengaged, and oxalic acid formed, together with a yellow substance precipitable by water, and which, when dried and heated explodes feebly. Potash ley and caustic ammonia dissolve a little of it at the boiling temperature. At 212° it is acted on by dry chlorine, muriatic acid is formed, and a dark-brown resinous substance is formed. It has some resemblance both in its appearance and in the blue colour which it strikes with sulphuric acid to the naphthalese of Laurent. But its constitution is quite different, being composed according to the analysis of Dr Gregory, of

* From Eblana, Dublin.

† xxi. 143. See also Jour. de Pharmacie, xxiii. 286.

Carbon	75·275 or	21 atoms =	15·75 or	per cent.	75·45
Hydrogen	5·609 or	9 atoms =	1·125	— —	5·39
Oxygen	19·116 or	4 atoms =	4·00	— —	19·16
	100·000		20·875		100·00

As no experiments have been made to determine the atomic weight of eblanin, these numbers can only give the ratios of the atomic constituents, and not the absolute number of atoms.

Dr Gregory, who published the first account of eblanin, has from its colour distinguished it by the name of pyroxanthin.*

SECTION XVII.—OF LAMP BLACK.

This pigment, as we learn from Pliny, was prepared by the ancients for the use of painters; and from the very short account which he gives, it would seem that the mode of manufacture was pretty much the same as that at present followed.†

It is usually prepared in this country from the refuse of resin, which is collected in the turpentine houses, where oil of turpentine is distilled. M. Funk gives us an account of the process followed in Sweden, for making lamp black, in 1754.‡ The impure resinous juice collected from incisions made in the pine or fir trees, is boiled down with a little water, and strained, while hot, through a bag. The dregs and pieces of bark left in the strainer, are burnt in a low oven, from which the smoke is conveyed through a long passage into a square chamber having an opening at the top, on which is a large sack, made of thin woollen stuff. The *soot*, or *lamp black* concretes partly in the chamber, from which it is swept out once in two or three days, and partly in the sack, which is now and then gently struck upon, both for shaking down the soot and for cleaning the interstices between the threads, so as to procure a sufficient draft of air through it to maintain the combustion.

At Ruchutte on the Saar, a coarser kind of lamp black is formed by the imperfect combustion of coal.§ In Great Britain, a very common substance for making lamp black is coal tar, obtained when coals are distilled for the manufacture of gas. Some years ago, Mr Macintosh made great quantities of excellent lamp black, by the imperfect combustion of coal tar.

The theory of the formation of lamp black is sufficiently obvious. The substances employed in the formation of it, consist chiefly of carbon and hydrogen, and of course they are either wholly or partially volatile. They are exposed to a heat sufficiently high to volatilize them, while the supply of air is not enough to burn them completely. The consequence is, that the hydrogen burns in preference, being converted into water, while the charcoal thus set at

* Ann. der Pharm. xxi. 143. † Plinii Hist. Mundi, lib. xxxv. cap. 6.

‡ Kong. Svensk Vet. Acad. Handl. 1754, xv. 106.

§ For a description of this manufacture, the reader is referred to the Jour. des Mines, x. No. 55, p. 487, where it is described at length by M. Duhamel fils.

liberty, is deposited under the form of soot or lamp black. This is the theory, also, of the appearance of smoke when oily or resinous bodies are burnt. The heat, and the supply of air not being sufficient to burn the whole, the least combustible ingredient, the charcoal, escapes, at least partly, and is deposited under the form of soot. Hence it is obvious that no smoke would appear, if the volatile matter from common coal, were to pass through a compartment sufficiently heated, and supplied with the requisite draft of air to consume the whole combustible matter.

Much attention is necessary in regulating the fire, during the preparation of lamp black. If it be too strong, the vapours would be too hot, and might scorch and destroy the woollen cloth which terminates the vent. If the fire be too low, the lamp black is heavy, which renders it of little or no value. For the goodness of lamp black, as a pigment, depends upon its lightness. So much is this the case, that the value of lamp black, however well prepared, may be destroyed by improper packing.

The lamp black, when properly prepared, is a fine black powder, exceedingly light, and capable of being mixed with oil and applied as a black paint. The only chemist who has examined it with attention, is M. Braconnot.* He does not inform us of the way in which the lamp black which he examined was prepared. But the sulphate of ammonia which he found in it, would seem to indicate that it had been prepared from *coal*. When digested in water, several salts were dissolved; for the liquid contained sulphuric and muriatic acids, lime, potash, and ammonia. When digested with oil of turpentine, that liquid acquires a strong yellow colour, and when distilled leaves a brown-coloured resin, very similar in its properties to Highgate resin. M. Braconnot found the constituents of the lamp black, which he analyzed, as follows:—

Carbon	79·1
Water	8·0
Resin	5·3
Bitumen	1·7
Sulphate of ammonia	3·3
Sulphate of lime	0·8
Quartzy sand	0·6
Ulmin	0·5
Sulphate of potash	0·4
Ferro phosphate of lime	0·3
Chloride of potassium	trace
	100·0

The *soot* which collects in common chimneys, where wood or pit coal is burnt as common fuel, differs very much from lamp black, and doubtless the soot of wood and of coal are not exactly alike. But hitherto wood soot alone has been subjected to an examination. We are

* Ann. de Chim. et de Phys. xxxi. 53.

indebted to M. Braconnot, for a chemical analysis of this kind of soot.*

Whoever has entered a Highland cottage, in which the smoke can make its escape only by the doors and windows, and which must therefore have the upper part of the room always full of smoke, must have observed, that all the rafters are black as jet, and shining as if covered with japan. Hence it is obvious, that a portion of the soot must have been deposited in a liquid state at first, and gradually assumed the consistence of pitch or resin, by exposure to the air. When we examine a chimney, at the bottom of which nothing is burnt but wood or peat, we find the soot at the lower end in brilliant masses, precisely similar to that which has attached itself to the rafters; but farther up in the chimney it has a pulverulent form. It was this last species of soot that Braconnot subjected to examination.

Soot, as is well known, has a black colour, an exceedingly disagreeable and bitter taste, and a peculiar and rather unpleasant smell. It burns like tinder, giving out during its combustion, a very disagreeable odour.

When boiled with water, it softens, and acquires a kind of ductility. The water assumes a dark brown colour, and lets fall on cooling, or at least when concentrated, a matter which has the appearance of pitch. This pitchy matter, when frequently boiled with new portions of water, is partly dissolved, and leaves a substance which no longer melts when heated, but which possesses all the characters of *ulmin*.

The portion dissolved in water, when obtained by evaporation and digested in alcohol, left a red substance having little taste, and destitute of bitterness. This substance is very soluble in water, and is doubtless of a peculiar nature. Braconnot calls it *animalized matter*, for what reason does not appear.

The portion dissolved in alcohol being obtained by evaporation, and digested in ether, gave out a yellow oily-looking matter to the ether, which had an exceedingly acrid and bitter taste. This substance Braconnot distinguishes by the name of *asbolin* (from ασβολη, *soot*).

It is fluid and not volatile. When mixed with a small quantity of cold water, it swims on that liquid like an oil; but if we increase the quantity of the waetr, we obtain a yellowish bitter solution. This solution is precipitated in yellow flocks by acetate of lead. With nitrate of silver it becomes slightly cloudy at first, but after standing some time, it assumes a brown colour, and a pellicle of metallic silver appears on the surface. Sulphated peroxide of iron, strikes with it a deep brown, almost black colour. Barytes water, lime water, ammonia, and the alkalies in general, strike with it an intense red colour. The infusion of nutgalls occasions a precipitate.

Alcohol dissolves it readily, and the solution does not become

* Ann. de Chim. et de Phys. xxxi. 37.

muddy when mixed with water. When heated, it burns with a strong flame like the fixed oils. But it is insoluble both in fixed oils, and in oil of turpentine.

Nitric acid dissolves it readily, giving it a reddish-yellow colour. The solution, evaporated to dryness, yields much yellow bitter principle, and very little oxalic acid.

The constituents of wood soot, according to the analysis of Braconnot, are the following:—

Ulmin	30·20
Animalized matter	20·00
Asbolin	0·50
Water	12·50
Carbonate of lime, with some carbonate of magnesia	14·66
Acetate of lime	5·65
Sulphate of lime	5·00
Acetate of potash	4·10
Charcoal	3·85
Ferro phosphate of lime	1·50
Silica	0·95
Acetate of magnesia	0·53
Chloride of potassium	0·36
Acetate of ammonia	0·20
Acetate of iron	trace
	100·00

No doubt other substances besides those discovered by Braconnot exist in soot. From its powerful anticeptic properties, we may be sure that creosote exists in it. It very probably contains also capnomore. Indeed we may look for most of the bodies recently discovered by Reichenbach.

SECTION XVIII.—OF ANIMAL CHARCOAL.

Though this substance, which of late years has become so important to manufacturers, be derived from the animal kingdom; yet as it undoubtedly owes its most important properties to the charcoal which it contains, it seems not improper to give an account of it here.

What is called *animal charcoal*, or *ivory black*, is prepared from the bones of horses, sheep, and oxen. These are exposed to heat in close vessels, so as to drive off all the volatile matter. The earth of bones remains mixed intimately with a quantity of charcoal, which gives the whole an intense black colour. They are afterwards reduced to powder, and are then fit for use. The value of ivory black depends much upon the way in which it is prepared. If it has been calcined at too high a temperature, it is not sufficiently porous; if too little, the animal matter remaining forms a kind of varnish, which covers the charcoal and prevents it from acting. The state of division in which animal charcoal is obtained has a great effect upon its value. Prussiate of potash, it is well known, is obtained by burning a mixture of potash and animal matters, such as blood,

horns, hoofs, &c., in iron pots. When this matter is lixiviated, an animal charcoal remains, much more efficacious as a discolouring principle, than that made from bones ever is. This may be partly owing to its state of more minute division; but undoubtedly the presence of the potash contributes also to the effect.

It was discovered by Lowitz of St Petersburg, in the year 1785, that common charcoal has the property of discolouring vegetable extracts.* And the discovery was prosecuted still farther, in a curious paper published by him in 1791.† In 1811 M. Figuier, apothecary at Montpelier, showed that animal charcoal is a much more powerful discolouring principle than vegetable charcoal.‡ This discovery was speedily applied in France to the refining of sugar, and a patent was soon after taken out in Great Britain for the use of animal charcoal, as a means of removing the brown colour from raw sugar, in the process of refining it. This patent was in force in 1815, when Mr Howard introduced his new method of boiling down sugar *in vacuo*, and obliged him to substitute, for animal charcoal, a mixture obtained by precipitating alum by means of lime. But animal charcoal is now universally employed in this country by the refiners of sugar.

When we employ animal charcoal in discolouring a liquid, we succeed much better if that liquid be slightly acid or neutral, than when it is alkaline. Hence animal charcoal is eminently powerful in discolouring wine or porter. Alkaline liquids sometimes, instead of being discoloured, acquire a deeper tinge when agitated with animal charcoal. This is owing to the presence of a brown matter in animal charcoal when not sufficiently calcined, which is soluble in alkalies. This substance possesses the characters of ulmin.

The action of animal charcoal on coloured liquids is usually more rapid when they are hot, than when they are cold. Hence it is usual to raise the liquid to be discoloured to the boiling temperature. The animal charcoal is then thrown in, and the whole is agitated for a short time, and then thrown on a filter. The liquid passes through colourless. We must not boil the liquid while in contact with the animal charcoal too long. For sometimes a portion of the colouring matter, after having been separated, is apt to be again dissolved. When this happens, the discolouring process is always incomplete, even when an unusual quantity of animal charcoal is used.

It would appear, from the following experiment of M. Bussy, that animal charcoal, when it discolours liquids, acts chemically upon the colouring matter. He diluted with water a quantity of indigo, dissolved in concentrated sulphuric acid, agitating the liquid with a sufficient quantity of animal charcoal, till it was completely discoloured. The animal charcoal, thus impregnated with

* Crell's Chemische Annalen, 1786, i. 211, &c.

† Ibid. 1791, i. 398 and 494. A translation of this last paper will be found in Crell's Journal, ii. 165, 237.

‡ Dumas, Traité de Chimie appliquée aux Arts, i. 448.

indigo, was washed with a great deal of water, but not a particle of the sulphate of indigo was dissolved. But when the charcoal was digested in a solution of potash, soda or ammonia, the sulphate of indigo was dissolved, and the liquid became blue. It would appear that animal charcoal acts the part of a weak base, and unites with the colouring matter as with an acid.

Animal charcoal being prepared from bones, contains always the calcareous salts of bones, namely, phosphates and carbonates of lime. Its constituents, in fact, are usually

Charcoal containing azote . .	10
Carburet, or silicet of iron . .	2
Phosphate and carbonate of lime .	88
Sulphurets of calcium and iron .	trace
	100

Now, M. Bussy has shown, that if we represent the discolouring power of animal charcoal by 100, and if we employ the ten per cent. of charcoal contained in it alone, its discolouring power is only 30. Yet he did not find that phosphate and carbonate of lime possessed any discolouring powers at all. This extraordinary fact cannot easily be explained, in the present state of our knowledge.

The state of division of the charcoal seems to have a great effect upon its discolouring powers. This is probably the reason why the mixture of potash and animal matters employed in the manufacture of prussiate of potash is so much more powerful as a discolouring substance than ivory black. M. Bussy has shown, that its discolouring powers are ten times greater than those of burnt bones. The charcoal derived from animal matters alone discolours but little. But when such charcoal is mixed with earthy salts, it discolours well, and best of all when the salts are present, while the charcoal is making. All this shows the effect of porosity on the goodness of the charcoal. Charcoal from animal matters alone is brilliant, and is obviously composed of compact plates. When earthy salts are present, the particles of charcoal are kept at a distance by the earthy matters, and this insulation of the particles is most complete when salts are present, in consequence of the constant motion of the pasty mass during the process of carbonization.

MM. Bussy and Payen have shown, that the goodness of animal charcoal as a discolouring principle depends upon these circumstances, and that it may be judged of with accuracy by its appearance: the more *brilliant* it is, the worse does it act, and the less lustre it has, the better does it act.

The following table, drawn up by M. Bussy, from his own experiments, will convey a better idea of the discolouring powers of animal charcoal in various states, than any description could do:—*

* Jour. de Pharm. viii. 257.

Charcoal employed. Weight always 1 dram.	Solution of indigo* discoloured in drams.	Solution of molasses discoloured in drams.	Ratio from the indigo.	Ratio from the molasses.
1. Charcoal of bones . .	32	9	1·00	1·00
2. Oil calcined with artificial phosphate of lime .	64	17	2·00	1·90
3. Charcoal of bones washed with muriatic acid .	60	15	1·87	1·60
4. No. 3, calcined with potash	1450	180	45·00	20·00
5. Lamp black calcined .	128	30	4·00	3·30
6. No. 5, calcined with potash	550	90	15·20	10·60
7. Charcoal of carbonate of soda decomposed by phosphorus . .	380	80	12·00	8·80
8. Do. of acetate of potash .	180	40	5·60	4·40
9. Flour calcined with potash	340	80	10·60	8·80
10. Albumen or gelatin calcined with potash . .	1115	140	35·00	15·50
11. Blood calcined with phosphate of lime .	380	90	12·00	10·00
12. Do. calcined with chalk .	570	100	18·00	11·00
13. Do. calcined with potash .	1600	180	50·00	20·00

CHAPTER XII.

OF NEUTRAL COMPOUNDS, OFTEN CONTAINING AZOTE.

These substances are obtained from plants by processes similar to those employed for obtaining the vegetable alkalies; and as their constitution is similar, it is rather difficult to form any conception of the reason why they do not participate in the power which these alkalies have to neutralize acids. Their number will doubtless increase very much when chemists have leisure to examine the whole vegetable kingdom with the same attention that has been paid to a few medicinal plants.

SECTION I.—OF STAPHYSIN.

This substance, at first confounded with *delphina*, was obtained in a separate state, by Couerbe, by the process described while treating of delphina, and was first made known and described by him in 1833, in his paper on *some quaternary substances of organic origin*.† It is a solid substance, of a slightly-yellow colour. Its

* The solution of indigo contained $\frac{1}{1000}$th of its weight of indigo. So that a dram contains the thousandth part of a dram of indigo.

† Ann. de Chim. et de Phys. lii. 363.

taste is exceedingly acrid. It melts when heated to the temperature of 392°, and at a higher temperature it gives out ammonia, and leaves a very great residue of charcoal.

Nitric acid, when assisted with heat, destroys its properties, and converts it into a bitter resin, acid, and having a good deal of the aspect of cholesteric acid. Chlorine, at the common temperature of the atmosphere, produces no sensible effect. At 300° it deepens the colour of staphysin, renders it very brittle, and deprives it of its bitter taste. The alkaloid thus altered is partly soluble in ether and alcohol; but the solution is not acrid.

It is very little soluble in water. The dilute acids dissolve it; but, according to Couerbe, do not form with it true salts.

Its constituents, according to the analysis of Couerbe, are

Carbon	72·67 or 32 atoms	=	24	or per cent.	73·28
Hydrogen	8·80 or 24 atoms	=	3	— —	9·16
Azote	5·35 or 1 atom	=	1·75	— —	5·34
Oxygen	13·18 or 4 atoms	=	4	— —	12·22
	100·00		32·75		100·00

Analogy leads to the conclusion, that these atomic proportions represent the constitution of staphysin. If so, its atomic weight must be 32·75.

SECTION II.—OF CAFFEIN.

A substance, to which the name *caffein* was applied, was discovered, in 1802, by Mr Chenevix.* It was obtained in a purer state by Runge,† in 1820, and Pfaff‡ described it about the same time, and distinguished it from caffeic acid. Robiquet again discovered it it 1821,§ and its properties were still farther examined by Pelletier‖ and Garot.¶ It may be obtained by the following process:—

A cold infusion of coffee is treated with acetate of lead, which throws down the colouring matter, and caffeic acid. A current of sulphuretted hydrogen gas is passed through the liquid to throw down the excess of lead added. The filtered liquid being now concentrated, the caffein is deposited in crystals.

These crystals are white, have a silky lustre, and they may be rendered purer by crystallizing them a second time.

The crystals are long needles, slightly flexible and transparent, and having a specific gravity of 1·23, at 65°$\frac{3}{4}$. The taste of caffein is very weak, but bitter and disagreeable. It is soluble, according to Pfaff, in 50 times its weight of cold water; but it is much more soluble in boiling water, and the solution, on cooling, deposits crystals, or rather is converted into a crystalline magma. It is not very soluble in absolute alcohol, but dissolves very well in spirits, of the specific gravity 0·837. Neither ether nor oil of turpentine are solvents of it. Neither acids nor alkalies produce any alteration on it, or

* Phil. Magazine, xii. 350. Chenevix's substance must have been caffeic acid.
† Materialien zur Phytologie. ‡ Schweigger Siedel's Jour. i. 487.
§ Jour. de Pharmacie, xii. 229. ‖ Ibid. ¶ Ibid. p. 234.

combine with it. Nitric acid does not decompose it, and when the acid is evaporated from crystals of caffein, they remain unaltered. When mixed with salts of the peroxide of iron, and black oxide of copper, it does not strike the green colour produced by the extract of coffee, and which Chenevix considered as characteristic of his caffein. It is neither precipitated by the acetate nor diacetate of lead.

When heated it melts easily into a transparent liquid, and if the heat be augmented, it sublimes in needles similar to those of benzoic acid. From a red hot platinum spoon it is volatilized without giving out any smell of ammonia or empyreumatic oil. We have four analyses of caffein, all differing so much from each other, that they cannot have been made upon the pure substance.

It will be sufficient to give that of Liebig, which, being the latest, and made with great care, is undoubtedly the most accurate. He obtained

Carbon	49·31 or 4	atoms = 3	or per cent.		49·49
Hydrogen	5·28 or $2\frac{1}{2}$	atoms = 0·3125	—	—	5·16
Azote	28·75 or 1	atom = 1·75	—	—	28·86
Oxygen	16·66 or 1	atom = 1·00	—	—	16·49
	100·00*	6·0625			100

It contains besides half an atom of water, which may be driven off by heat. Liebig considers it as a compound of cyanic acid (containing half its usual dose of oxygen) and half an atom of ether. This supposition agrees very well with the atomic constituents.

MM. Robiquet and Boutron have lately found the quantities of caffein in 100 parts of different varieties of coffee, as follows :—†

	Caffein.
Martinique coffee . . .	6·4
Alexandria coffee . . .	4·4
Java coffee	4·4
Mocha coffee	4·0
Cayenne coffee	3·8
St Domingo coffee . . .	3·2‡

* Annalen der Pharmacie, i. 17. He found that 938 parts of dry caffein gave 1696 parts by weight of carbonic acid, and 446 water. The volume of azotic gas was to that of the carbonic acid gas given out, when the caffein was decomposed by oxide of copper, as 1 to 4. Hence the numbers in the text.

† Jour. de Pharmacie, xxiii. 109.

‡ Since the imperfect account of *theina*, given in page 295 of this volume, was printed, I have seen the analysis of it by M. Jobst of Stutgard, from which it appears to be identical in its composition and characters with caffein.*

He prepared it by boiling tea leaves in water, filtering and concentrating the solution, and then mixing it with acetate of lead, till all precipitation was at an end. He then filtered and threw down the excess of lead by sulphuretted hydrogen. Being now concentrated sufficiently, in was deposited in soft needles, which were purified by solution in alcohol.

It is snow-white, and in fine needles, having a silky lustre. Does not act on vegetable blues. Much more soluble in hot than in cold water, alcohol, and ether. Dissolves readily in acids, and is decomposed when heated with sulphuric

* Annalen der Pharmacie, xxv. 63.

SECTION III.—OF PIPERIN.

M. Orstedt first announced, in 1819, the existence of a peculiar principle in the fruit of *piper nigrum*, or *black pepper*,* to which he gave the name of *piperin*. In 1821 an elaborate analysis of black pepper was made by Pelletier, who also obtained piperin, and described its properties.† In 1832 an analysis of it was published by Liebig.‡ It may be obtained by the following process:—

Boil pepper in alcohol. Distil off the alcohol, and wash the dry residue with water. What remains undissolved by the water is to be dissolved in hot alcohol. Set the solution aside for a few days, that it may have time to deposit crystals. These crystals may be freed from a greenish-white resin, by washing them in water, and dissolving them in alcohol, and crystallizing from the solution.

It crystallizes in oblique four-sided prisms, whose faces are inclined to each other at angles of about 85° and 95°. When heated to about 212°, it melts into a light yellow transparent oil, which hardens, on cooling, into a light yellow, translucent, resinous-like matter. It has very little taste, and that little is probably derived from some oil of pepper, from which it is very difficult to free it completely. It is insoluble in cold, and but slightly soluble in boiling water.

It is very soluble in alcohol; less so in ether: but it dissolves better in these liquids while hot than while cold. Acetic acid is also a good solvent of it. Dilute sulphuric, nitric, and muriatic acids do not act sensibly on it. But when these acids are concentrated, they alter its nature. Concentrated sulphuric acid gives it a blood-red colour; but the colour disappears if the acid be diluted with water. Muriatic acid acts in the same way, except that the colour produced is not red, but an intense yellow. Nitric acid renders it first greenish-yellow, then orange, and at last red. By long-continued action, oxalic acid and a bitter matter are formed.

When piperin is distilled, it produces water, acetic acid, oil, and carburetted hydrogen gas; but no ammonia.

Its constituents, as determined by the analysis of Liebig,§ are

---

or nitric acid. It is not precipitated from its acid solutions by alkalies. When boiled with concentrated potash ley it is decomposed, and ammonia disengaged. It may be sublimed, and contains water of crystallization, which it loses at 212°.

According to the analysis of Jobst, theina is composed of

Carbon	49·60
Hydrogen	5·22
Azote	28·91
Oxygen	16·27
	100·00

Numbers almost identical with those obtained by Liebig from caffein.

It is clear, that neither theina nor caffein constitutes the principle to which tea and coffee are indebted for their peculiar properties.

* Jour. de Phys. xc. 173.

† Ann. de Chim. et de Phys. xvi. 337.

‡ Ibid. li. 441.

§ Annalen der Pharmacie, vi. 36.

Carbon	69·78 or	40 atoms =	30	or per cent.	70·58
Hydrogen	6·69 or	22 atoms =	2·75	— —	6·48
Azote	4·10 or	1 atom =	1·75	— —	4·12
Oxygen	19·43 or	8 atoms =	8·00	— —	18·82
	100·00		42·50		100

If we abstract 2 atoms of water, we have the formula for piperin, C^{40} H^{20} Az O^{6}. Now, this corresponds with the constitution of narcotin; only, it contains but half the number of atoms of oxygen.

SECTION IV.—OF DAPHNIN.

Vauquelin made some experiments on the bark of the *daphne alpina*,* and extracted an acrid volatile substance, soluble in water, to which Berzelius has given the name of daphnin. In the year 1822, MM. C. G. Gmelin and Baer published an elaborate set of experiments on the bark of the *daphne mezerium*, or common mezerion, so frequent in our shrubberies, in consequence of the beauty and early appearance of its blossoms.† Among many other constituents of this acrid bark, they discovered a crystallized body, which they examined, and to which they gave the name of *daphnin*. We shall apply this name to the substance described by these chemists, as the nature of Vauquelin's principle still remains uncertain.

Gmelin and Baer obtained the *daphnin* in the following way:—

The alcoholic solution of the bark was mixed with water, and the alcohol distilled off, and the residual liquid was precipitated by acetate of lead. The precipitate thus obtained was washed with cold water, and decomposed by a current of sulphuretted hydrogen gas, and the liquid filtered and evaporated to dryness. The residual matter was digested in cold absolute alcohol, and the alcoholic solution left to spontaneous evaporation. The daphnin was deposited in small crystals, while malic acid and brown colouring matter remained dissolved in the residual liquid. Gmelin found that daphnin existed also, and in greater quantity, in the bark of the daphne alpina.

Daphnin thus obtained is but little soluble in cold water, but very soluble in boiling water; and, as the liquid cools, it is deposited in colourless crystals, having a bitter and slightly-astringent taste. It is soluble in alcohol and ether. The solutions are coloured yellow by alkalies; but the colour disappears when the alkali is saturated with an acid.

According to Gmelin and Baer, daphnin is neither acid nor alkaline, and they consider it as analogous to asparagin. Nitric acid converts it into oxalic acid. Acetate of lead does not precipitate pure daphnin from its solutions, but a partial precipitation takes place when the solutions contain a mixture of foreign matter.

When heated in a retort it melts, then swells up, and becomes

* Ann. de Chim. lxxxiv. 173. † Schweigger's Jour. xxxv. 1.

black, and gives out an acid vapour. When thrown upon red hot charcoal it exhales a pungent vapour.

No attempts have been made to ascertain the ultimate constituents of this substance, nor to determine its action upon the animal economy.

SECTION V.—OF JALAPPIN.

This substance was first obtained by Mr Hume in 1824,* by the following process:—

Jalap, which is the root of the *convolvulus jalappa*, is powdered and macerated for a couple of weeks in weak acetic acid. A dark-coloured solution is obtained, which is filtered, mixed with caustic ammonia, and well agitated. A gritty powder falls, consisting of small crystalline grains, which is to be washed in cold water. Being again dissolved in acetic acid, and thrown down by ammonia, it is obtained in small needles.

Jalappin thus obtained has a snow-white colour, but is destitute of taste and smell. It is insoluble in cold, and but little soluble in boiling water. It dissolves readily in alcohol, but is insoluble in ether. An ounce of jalap yields about 5 grains of this substance.

How far this jalappin of Hume constitutes the principle to which that root owes its peculiar medical properties, is doubtful. Schweinsberg assures us that it is nothing else than ammonia—phosphate of magnesia mixed with some lime and organic matter.

Herberger states that when the resin of jalap is dissolved in alcohol, and mixed with an alcoholic solution of acetate of lead, a precipitate falls, consisting of oxide of lead united to resin, which acts the part of an acid. When the residual liquid is freed from lead and acetic acid, it yields a transparent colourless resin, which is very soluble in alcohol.

To this substance M. Herberger has given the name of *jalappin*. Concentrated acetic acid dissolves it completely, especially when assisted by heat. It is soluble also in sulphuric, nitric, phosphoric, and muriatic acids.†

We do not know whether these two substances be identical, but it is probable that they are.

SECTION VI.—OF SINAPIN.

MM. Henry and Garot,‡ extracted a substance from the seeds of *sinapis alba* and *nigra*, to which they gave the name of *sulphosinapisin*, a name afterwards shortened into *sinapin*. It may be obtained by the following process:—

Subject mustard seeds to pressure, to separate from them their fixed oil. Boil the residual matter with water, and evaporate the decoction on the water-bath to the consistence of honey. Mix this residue with 6 or 8 times its volume of absolute alcohol to precipitate the gum, mucilage, colouring matter, and the acetate, citrate,

* Medical and Phys. Jour. for 1824, p. 246.

† Berzelius, Traité de Chimie, v. 526. ‡ Jour. de Pharmacie, xvii. 1.

and phosphate of lime. Distil the alcoholic solution, and leave the syrupy residue in a state of rest. It gradually deposits abundance of crystals of *sinapin*. Separate the mother water, and concentrate it to obtain an additional quantity of sinapin. Dissolve the sinapin repeatedly in alcohol, and crystallize in order to obtain it in a state of purity.

Sinapin thus obtained possesses the following properties:—It is white, very bulky and light. Its taste is at first bitter, and then analogous to that of mustard. It dissolves with a yellow colour in water and alcohol, and if it be dissolved in these liquids while hot, it crystallizes when they cool. The crystals are small needles grouped together in bundles. It crystallizes from an acid solution preserving its original properties. It is perfectly neutral. When distilled it gives out ammonia, partly combined with carbonic acid, and partly with sulphuretted hydrogen.

When the solution of sinapin is mixed with chlorine, it assumes a brown colour, sulphuric acid is formed, and the smell of hydrocyanic acid becomes evident. When we distil sinapin with sulphuric or phosphoric acid and water, we obtain in the receiver an acid liquor, which strikes a red with the persalts of iron, and produces a white precipitate in a solution of sulphate of copper containing iron; showing the presence of hydrosulphocyanic acid in the liquid.

Nitric acid dissolves sinapin, and assumes a deep-red colour, nitrous gas is disengaged and sulphuric acid formed. Muriatic acid gives sinapin a green colour, and when heat is applied, hydrocyanic acid is disengaged.

The solution of sinapin in potash assumes at first a deep-yellow colour, and then becomes green. Acids dropt into this solution or into that of sinapin in an alkaline earth precipitate the greatest part of the sinapin unaltered. It is obtained in the same state by evaporating the ammoniacal solution of it. But when we heat mixtures of dry sinapin, and salifiable bases, a sulphocyanet is formed.

Sinapin throws down a cheesy precipitate from nitrate of silver. If we precipitate a solution of nitrate of silver as exactly as possible by sinapin, and then decompose by sulphuretted hydrogen the excess of the silver salt in the liquid, and saturate the nitric acid exactly with potash, and evaporate the liquid, a green-coloured organic substance is obtained.

According to Henry and Garot, sinapin is composed of

Carbon	57·920	or 24 atoms =	18
Hydrogen	7·795	or 22 atoms =	2·75
Azote	4·940	or 1 atom =	1·75
Sulphur	9·657	or 2 atoms =	4
Oxygen	19·688	or 7 atoms =	7
	100·000		33·5

SECTION VII.—OF COUMARIN.

In the year 1820, M. Vogel announced that *Tonka bean*, which

is the fruit of the *coumarouna oderata*, contained benzoic acid.* The resemblance between the smell of the Tonka bean and the flowers of the *melilotus officinalis* led him to examine these flowers also, and he assures us that he found the same acid in them. Soon after M. Guibourt ascertained that the crystalline matter in the Tonka bean was not benzoic acid, but a peculiar substance which he distinguished by the name of *coumarin*. In 1825, MM. Boullay and Boutron-Charlard published a chemical examination of the Tonka bean,† in which they confirmed the accuracy of M. Guibourt's statements, and adopted the name *coumarin*, to distinguish that substance.

Still more lately, MM. Chevallier and Thubeuf announced‡ that in the water distilled from the melilot, they had found a peculiar crystallized substance, which in their opinion possessed alkaline characters. This announcement induced M. Guillemette to make a set of experiments on the subject.§

The tops of the flowers of melilot, reduced to a coarse powder, were treated with alcohol of 0·842 till they ceased to communicate any colour to that liquid. The tinctures were mixed together, and the alcohol distilled off. The residue, put into a porcelain capsule, and left at rest for twenty-four hours, became covered with a layer of half solid fatty matter, which was carefully removed. The liquid was then evaporated to the consistence of a syrup, and left at rest for forty-eight hours. A number of crystalline needles were deposited which were thrown on a cloth and washed with cold water. The mother water when concentrated yielded more of these crystals. These crystals were dissolved in water and treated with animal charcoal. Being now crystallized again they were in a state of purity. These crystals thus obtained are identical with the coumarin from the Tonka bean.

The crystals are either silky needles or short prisms. The taste is sharp, but leaves an agreeable impression in the mouth. Coumarin is heavier than water. It melts in a very gentle heat, and crystallizes again confusedly when allowed to cool. It sublimes very easily, and crystallizes in needles.

It is not sensibly soluble in cold water. Boiling water dissolves it readily and allows it to crystallize on cooling. When we add to water more coumarin than it is capable of dissolving, the excess melts and forms an apparently oily stratum at the bottom of the vessel. When distilled along with water, the liquid that comes over possesses the characters of common melilot water.

Alcohol and ether dissolve coumarin at the ordinary temperature of the atmosphere. And it is easily obtained in crystals by leaving these solutions to spontaneous evaporation. Diacetate of lead throws down a copious white precipitate. Neither ammonia nor caustic potash dissolve it. At the common temperature of the atmosphere both sulphuric and nitric acids dissolve a great quantity

* Jour. de Pharmacie, vi. 305. † Ibid. xi. 480.
‡ Jour. de Chim. Med. x. 350. § Jour. de Pharmacie, xxi. 172.

of coumarin, without altering its nature. These solutions are precipitated by water. The dissolving power of these acids diminishes with their concentration. When nitric acid is assisted by heat, it gives coumarin a yellow colour, but no oxalic acid is formed. Phosphoric, tartaric, and acetic acids dissolve it more or less. The same acids, diluted with a great deal of water, dissolve it when hot; but no combination takes place, and the coumarin crystallizes when the solution cools.

Coumarin was analyzed by M. Henry, who obtained

Carbon	76·40 or	10 atoms = 7·5	or per cent.		75·98
Hydrogen	3·89 or	3 atoms = 0·375	—	—	3·78
Oxygen	19·71 or	2 atoms = 2·0	—	—	20·24
	100·00	9·875			100·00

The identity of coumarin and the crystals from melilot has been established. It neither possesses the alkaline qualities ascribed to it by Chevallier and Thubeuf, nor the acid qualities given it by Vogel; but appears to be a neutral substance.

SECTION VIII.—OF HESPERIDIN.

This substance was discovered by M. Lebreton, in 1828, in the unripe fruits of different species of orange and lemon trees.* To obtain it we must take unripe oranges after they have obtained a diameter of about half an inch. The white portion of the rhind is freed from the outer green covering, and from the innermost part of the fruit. It is then digested in water, of a temperature between 75° and 86°; the liquid is filtered and concentrated to $\frac{3}{4}$ths of its original bulk. A little albumen precipitates which must be separated. The malic acid which the liquid contains must now be saturated with lime, and the whole evaporated to the consistence of a syrup. This syrup being digested in alcohol of the specific gravity 0·817, gum, albumen, a brown bitter matter, and malate of lime are left undissolved. The solution being filtered and evaporated to dryness, the granular extract remaining is to be mixed with 20 times its weight of water, or distilled vinegar, and often agitated. This clear liquid being drawn off and left undisturbed for eight days, the hesperidin is deposited in small crystals, which must be carefully washed. The distilled vinegar deposits the hesperidin much more rapidly than water, and is therefore to be preferred as a solvent.

Hesperidin, thus obtained, has the form of soft silky needles, without smell, and at first appearing tasteless; but leaving a bitter impression in the mouth. It melts when heated a little above the temperature of 212°, and while in fusion has the aspect of a resin; on becoming solid it preserves its transparence, assumes a yellowish colour, and becomes electric when rubbed. It is no longer crystallizable, and its taste is sweetish and bitter. At a somewhat higher temperature, hesperidin is completely decomposed.

* Jour. de Pharmacie, xiv. 377.

It is little soluble in cold water; but boiling water dissolves about $\frac{1}{600}$th of its weight of it. It is not more soluble in cold alcohol; but boiling alcohol dissolves it much more abundantly, and when the solution cools, a portion of the hesperidin is deposited. It is insoluble in ether, in fixed and in volatile oils. It has no action on litmus paper. The dilute acids do not dissolve it. Concentrated sulphuric acid gives it a red colour. Concentrated acetic acid dissolves a small quantity of it, which crystallizes when we evaporate the acid. It is soluble in the alkaline leys. Diacetate of lead does not throw it down. When the aqueous solution of it is mixed with the sulphated peroxide of iron, a brownish-red precipitate falls.

M. Widnmann, of Munich, obtained from the rhinds of unripe oranges a substance differing from the hesperidin of Lebreton. It was crystallized in prisms, insoluble in alcohol, soluble in water, and not forming oxalic acid when acted on by nitric acid.*

SECTION IX.—OF POPULIN.

This principle was discovered in 1830 by Braconnot, in the bark of the *populus tremula*,† where it is accompanied by salicin. He found afterwards, that the leaves of the tree furnish it in greater abundance. It may be extracted by the following process:—

Boil the leaves in water, and pour diacetate of lead into the decoction. A fine yellow precipitate falls. Filter the liquid and evaporate it to the consistence of a syrup. When it cools, the *populin* separates under the form of a very bulky crystalline precipitate. Subject it to strong pressure between folds of linen cloth, then heat it with 160 times its weight of water, and a portion of ivory black, and filter the liquid while boiling hot. On cooling it deposits abundance of populin in fine silky needles. When dried on blotting paper it is a very light substance, having a snow-white colour.

Populin has a sweet taste, not unlike that of liquorice. It requires about 2000 times its weight of cold water to dissolve it; but it dissolves in about 70 times its weight of boiling water. It is not affected by the greater number of the metalline salts. But chloride of sodium throws it down unchanged, and in the form of crystals. Boiling alcohol dissolves it very well, and when the liquid cools the populin is deposited in such abundance as to convert the whole liquid into a crystalline magma.

It is very soluble in acetic acid, and nitric acid, and it may be precipitated from these solutions by the alkalies. Phosphoric acid dissolves it also; but when that acid is too concentrated, it converts it at once into a resin. The weak mineral acids when hot act upon it as they do on salicin: they convert it into a white resinous powder, quite similar to that produced from salicin. Like salicin, it gives a purple-red solution with concentrated sulphuric acid.

When treated with nitric acid it furnishes, as is the case also with

* Jour. de Pharmacie, xvi. 707. † Ann. de Chim. et de Phys. xliv. 296.

salicin, a great quantity of carbazotic acid, but no oxalic acid. When heated sufficiently with potash, it is converted into oxalic acid, as is the case with almost all organized bodies. When heated it first melts into a transparent and colourless liquid; it then burns with a strong flame, giving out at the same time an aromatic odour. When distilled, it seems to yield an empyreumatic oil, and benzoic acid.

Chlorine and iodine have no marked action on populin. The febrifuge virtues of this substance have not been tried; but it is probable, from its great resemblance to salicin, that it is not destitute of them.

SECTION X.—OF PLUMBAGIN.

This substance was discovered by M. Dulong d'Astafort, in the root of the *plumbago Europæa*, in 1828.* The bark of the root contains the most of it, and it may be extracted in the following manner:—

Digest the bark in ether till that liquid refuse to take up any thing more. Mix the ethereal solution with water, and distil off the ether. Raise the aqueous solution to the boiling temperature, and draw off the clear liquid while boiling hot. On allowing it to cool, plumbagin is deposited. Boil the liquid again and allow it to cool. Another crop of plumbagin will be obtained. Repeat this process till the liquid is exhausted of plumbagin. The plumbagin thus obtained is to be boiled in alcohol or ether, and the solution left for spontaneous evaporation. The plumbagin gradually crystallizes either in fine needles or in elongated pyramids. The colour is lemon yellow, and the crystals have considerable brilliancy. The taste is sweetish, but it leaves an acrid hot impression in the mouth.

It melts in a gentle heat, and on becoming solid, assumes a crystalline appearance. When heated more strongly it partly sublimes, but the greatest part of it is decomposed, leaving a charcoal which has a good deal of the metallic lustre. No ammonia is evolved during this distillation.

Plumbagin is very little soluble in cold water, to which, however, it communicates a yellow colour. Boiling water dissolves it better, and allows it to fall, on cooling, in yellow flocks. It is very soluble in alcohol and ether. The concentrated acids dissolve it, and water precipitates it from these solutions, but the precipitation is not complete; because it is more soluble in dilute acids than in water. The alkalies dissolve it readily and give it a red colour. The addition of an acid restores the yellow colour of the plumbagin.

Plumbagin is exceedingly sensible to the presence of bases: the hydrate of alumina reddens it, and when poured into a solution of diacetate of lead, a crimson-red precipitate is gradually induced.

* Jour. de Pharmacie, xiv. 441.

CHAPTER XIII.

OF MELLON, AND SOME ANALOGOUS COMPOUNDS OF AZOTE.

SECTION I.—OF SULPHURET OF CYANOGEN.

If we dissolve sulpho-cyanodide of potassium in water, and pass a current of chlorine through the liquid, or if we boil it with dilute nitric acid, an orange-yellow coloured body precipitates, to which Liebig has given the name of *sulphuret of cyanogen.**

When this body is dried and heated, it undergoes decomposition. A considerable quantity of sulphur and bisulphuret of carbon is obtained, and there remains a lemon-yellow powder. Now, as the only substances produced during this decomposition are the yellow powder, sulphur, and bisulphuret of carbon; it is clear that the yellow powder must contain more azote than cyanogen. Liebig distinguishes this yellow powder by the name of *Mellon.*

SECTION II.—OF MELLON.†

This substance was first observed by Berzelius, while distilling the sulpho-cyanodide of mercury.‡ But he made no experiments to determine its nature. He showed, however, that it was more fixed than mercury. Sulpho-cyanodide of mercury gives the same products as sulphuret of cyanogen; but instead of sulphur, we obtain sulphuret of mercury.

Mellon, if it has been exposed to a red heat, contains no sulphur. It is insoluble in water, and in all neutral liquids, which do not alter its nature.

When heated to the temperature at which bottle glass softens, it is decomposed into pure cyanogen and azotic gases, in such proportions, that out of 4 volumes of the gas, 3 are absorbed by potash, and the one remaining is azotic gas. When burnt with black oxide of copper, it is converted into carbonic acid and azotic gases, in the proportion of 3 volumes of the former, to 2 of the latter. It is therefore composed of

6 atoms carbon	4·5
4 atoms azote	7
	11·5

It is easy to explain the formation of this substance.

* See an account of this substance by Liebig, in Poggendorf's Annalen, xv. 549. It appears from his analysis to be a compound of

2 atoms sulphur	4
1 atom cyanogen	3·25
	7·25

† Liebig, Ann. de Chim. et de Phys. lvi. 8.

‡ Traité de Chimie, iv. 377.

If from	2 Sulphuret of cyanogen .	$C^4\ Az^2$	S^4
we take	1. 1 bisulphuret of carbon	C	S^2
	2. 2 sulphur . . .		S^2
There will remain . . .		$C^3\ Az^2$	

or half an atom of mellon.

If we heat mellon in dry chlorine gas, we obtain a white product, having a pungent smell, and acting strongly on the eyes. The same substance seems to be formed when we heat together, 2 parts of corrosive sublimate, and 1 part of sulphocyanodide of potassium. The two substances when slightly heated, melt, act violently on each other, swell up, and bisulphuret of carbon is disengaged.

When mellon is heated with potassium, a combination takes place with the evolution of light. The product is a transparent mass, easily fusible. It dissolves in water, and the solution has the flavour of bitter almonds; but contains no trace of oxalate or cyanodide. It precipitates the metals; but the precipitates have no resemblance to cyanodides. The aqueous solution is decomposed by the addition of an acid. A bulky precipitate falls in white flocks, which is readily soluble in an excess of alkali.

At the instant of the combination of mellon with potassium, a slight smell of ammonia is perceptible. This doubtless is occasioned by the hydrogen of a trace of naphtha not removed from the potassium.

Liebig endeavoured to obtain mellon in large quantities by decomposing sulpho-cyanodide of potassium, by means of chlorine. If we heat this sulphocyanodide above its point of fusion in a current of dry chlorine gas, a violent decomposition takes place all at once. Thick red vapours are disengaged, which are deposited in red leaves on the walls of the retort. We obtain in this way, for volatile products, chloride of sulphur, and the chloride of cyanogen discovered by Serullas.

At a gentle heat, which ought not to exceed the point at which the sulphocyanodide of potassium melts, there distils over chloride of sulphur, accompanied by another product, and at the end of the distillation, chloride of cyanogen is deposited in long needles, in the neck of the retort.

The residue contained in the retort presents, when we separate it by washing with water, from chloride of potassium with which it is mixed, a substance of a light-yellow colour, which, when dry is a light powder. This substance, after exposure to a red heat, is pure mellon.

Mellon, when heated in a solution of hydrate of potash, dissolves with the evolution of ammonia. During the solution, there is formed a great number of long silky transparent crystals, which on cooling increase so as to fill the whole liquid. The evolution of ammonia shows that the substance which combines with the potash, contains less azote than mellon does.

Mellon dissolves likewise in nitric acid. During the boiling, we

observe a continual effervescence without the disengagement of nitrous gas. There is formed in the liquid, which is very acid, and which contains ammonia, a peculiar acid in long needles. This is *cyanilic acid*. It has been described in this work, in page 211.

Leopold Gmelin, during the preparation of sulphocyanate of potash, obtained occasionally a small quantity of a peculiar salt. When the mixture of prussiate of potash and sulphur was heated above the point at which it ceases to strike a blue with the salts of iron, then dissolved in water, the iron precipitated by potash, and the residue boiled in alcohol, and the filtered solution set aside for some time in a cold place, cauliflower-shaped crystals of this peculiar salt are deposited. These crystals were redissolved in water, crystallized a second time, and pressed between folds of blotting paper. Being now washed with hot alcohol, till they ceased to give a red colour to the persalts of iron, the salt was freed from the sulphocyanate of potash, with which it had been originally mixed. To the acid contained in this salt, M. L. Gmelin has given the name of *hydromelonic*.*

This acid may be obtained in the following manner:—The hot solution of the salt is decomposed by concentrated acetic acid, which throws down a white flocky precipitate. To obtain the whole acid, the mixture is evaporated to dryness, the acetate of potash is removed by alcohol, and the acid remains on the filter.

Hydromelonic acid, thus obtained, is a white earthy powder, destitute of taste and smell. When dissolved in boiling water, it scarcely reddens litmus paper.

When heated in a glass tube, over a spirit lamp, it effervesces slightly, and is converted into a lemon-yellow matter (Mellon), which by continuing the heat is entirely dissipated. There passes over, first a watery vapour, then a great deal of hydrocyanate of ammonia, which concretes on the upper part of the tube, while on the lower part, a white opaque body is deposited, which, by continuing the heat, is converted into an aqueous solution of potash.

The acid dissolves easily and abundantly in nitric acid. When diluted with water, the solution becomes milky. The nitric acid may be evaporated away, leaving the hydromelonic acid unaltered.

Sulphuric acid dissolves it, though more slowly, and the solution becomes muddy when water is added.

It is but slightly soluble in cold, but more so in boiling water. When this last solution is allowed to cool, most of the acid is precipitated. Alcohol acts like water, except that it takes up less of the acid.

To analyze this acid, Gmelin employed hydromelonate of lead, dried in the open air at 60°, 100 parts of this salt exposed to a heat of 212°, lost 11·087 parts of water, and when the heat was raised to 248°, it underwent an additional loss of 3·043, making the whole water disengaged, 14·13 parts.

* Ann. der Pharm. xv. 252.

100 parts of the same salt being decomposed by sulphuric acid, left 62·38 of sulphate of lead, equivalent to 45·964 of oxide of lead. Hence the constituents of the salt were

Hydromelonic acid	39·906	or 12·154
Oxide of lead .	45·964	or 14
Water . . .	14·130	
	100·000	

This analysis gives us the atomic weight of hydromelonic acid 12·154.

Leopold Gmelin analyzed hydromelonate of lead by means of oxide of copper, and obtained

Oxide of lead	45·964 or 1 atom	= 14	or per cent.	46·46
Carbon	14·720 or 6 atoms	= 4·5	— —	14·94
Hydrogen	2·037 or 5 atoms	= 0·625	— —	2·08
Azote	23·010 or 4 atoms	= 7·0	— —	23·24
Oxygen	14·269 or 4 atoms	= 4	— —	13·28
	100·000	30·125		100·00

But a considerable portion of the oxygen and hydrogen was in the state of water, obviously 4 atoms, of which 3 were driven off by the water bath, and 1 at the temperature of 248°. Subtracting these 4 atoms, and the atom of oxide of lead, the hydromelonic acid is obviously composed of

6 atoms carbon . . .	= 4·5
4 atoms azote . . .	= 7
1 atom hydrogen . .	= 0·125
	11·625

So that its true atomic weight is 11·625, and it is composed of an atom of mellon, and an atom of hydrogen.

The hydromelonate of potash, discovered by L. Gmelin, is a yellowish-white opaque cohesive mass, having a bitter taste. When heated, it gives out carbonate and hydrocyanate of ammonia, and melts into a clear yellow liquid, which concretes on cooling. When heated with nitric acid, it froths, but without any effervescence. It dissolves in hot sulphuric acid, and is precipitated again by water. It is scarcely soluble in cold, but very soluble in hot water. Alcohol scarcely acts upon it, even at a boiling temperature. It is decomposed by all the stronger acids, the hydromelonic acid being disengaged. The earthy alkaline salts, earths, and most of the metallic salts, occasion a precipitate in hydromelonate of potash, of flocks most commonly white, but the oxide of chromium salts, give a bluish-white, those of peroxide of iron, a light-brown, those of oxide of cobalt, rose red, of nickel oxide, bluish-white, of suboxide of copper, lemon yellow, of black oxide of copper, sisken-green, of gold oxide, yellowish-white, and of platinum oxide, brownish-yellow.*

* L. Gmelin, Ann. der Pharmacie, xv. 252.

SECTION III.—OF MELAM.*

The preparation of sulphocyanodide of ammonium in a dry state, is attended with difficulties, in consequence of the readiness with which it absorbs moisture from the atmosphere, and runs into a liquid. M. Liebig therefore substituted a mixture of 2 parts sal ammoniac, and 1 part sulphocyanodide of potassium, which, when heated, yield precisely the same volatile products.

According to Liebig, sulphocyanodide of ammonia, and urea are composed of the same constituents, namely, C^2 H^4 Az^2 O^2 (substituting O^2 for S^2.

When raised to a temperature a few degrees higher than the boiling point of water, it undergoes decomposition, and so much the more completely the slower the temperature is raised.

The first effect of the heat is to disengage a notable quantity of ammoniacal gas. After a certain time bisulphuret of carbon appears, and in the neck of the retort a number of crystals of *sulphuret of ammonium* is collected.

The quantity of ammonia disengaged is so great, that all the bisulphuret of carbon (which is under the form of gas) mixes with it, and does not condense on cooling. But if we connect the retort with the refrigerating apparatus, we see, for every bubble of ammonia which condenses, a drop of bisulphuret of carbon fall to the bottom. The bisulphuret of carbon formed during this process amounts to $\frac{1}{4}$th of the sulphocyanodide of potassium employed.

During the whole course of the distillation no permanent gas is disengaged. The sulphocyanodide of ammonium is entirely decomposed into ammonia, bisulphuret of carbon, sulphuret of carbon, sulphuretted hydrogen, and a new substance, to which M. Liebig, the discoverer, has given the name of *melam*. There remains in the retort this new substance, mixed with chloride of potassium and sal ammoniac, which last had been added in excess.

By washing this residue in a sufficient quantity of water, the melam may be obtained in a state of purity. Melam, when pure, has a grey colour. It is insoluble in water, alcohol, and ether. It contains no sulphur as a constituent, but sometimes sulphur is mechanically mixed with it, when the sulphocyanodide of potassium employed in its preparation has been too strongly heated. But it may be freed from this sulphur by simple levigation, it being mixed with it in the state of a heavy powder.

Melam is decomposed by a strong heat; ammonia is disengaged; a crystalline matter is sublimed in small quantity; and there remains a yellow substance which, at a red heat, is decomposed into cyanogen and azote.

If we heat this residue merely till it become yellow, it gives when boiled with potash, the same crystalline substance mentioned, when treating of melam.

By boiling, melam dissolves in hydrate of potash of moderate

* Liebig, Ann. de Chim. et de Phys. lvi. 16.

strength, and by continuing the action we may decompose the melam entirely. But if we filter the liquid before the melam is wholly dissolved, there precipitates a white heavy powder, which is *melam* in a state of purity.

M. Liebig employed this pure melam to determine its composition.

He found that, when burnt by means of oxide of copper, the gases evolved were azotic gas, and carbonic acid gas in the proportion :: 11 : 12.

He obtained from 100 parts of melam 110·2 of carbonic acid, and 35·4 of water. Hence the constituents are,

Carbon	30·05
Hydrogen	3·93
Azote	66·02
	100·00

M. Liebig deduces from these numbers the following atomic constitution of melam :—

6 atoms carbon	= 4·5	or per cent.	30·64
$4\frac{1}{2}$ atoms hydrogen	= 0·5625	— —	3·83
$5\frac{1}{2}$ atoms azote	= 9·625	— —	65·53
	14·6875		100·00

The decomposition of melam by the acids is very singular. If we boil it with concentrated nitric acid till it is entirely dissolved, we obtain, when the liquid cools, a quantity of transparent crystals, which possess all the properties of an acid. This acid is the *cyanuric** in a state of purity. During this decomposition no nitrous gas is evolved, but ammonia is formed, and found combined with the nitric acid.

When melam is fused with hydrate of potash it behaves exactly as with nitric acid only, instead of cyanuric acid, *cyanic* acid is formed. The mass froths violently, a great quantity of ammonia is disengaged, and if the melam is sufficient we obtain neutral cyanate of potash, which fuses with facility. The fused mass is as liquid as water, and, on cooling, assumes the form of a transparent crystalline mass.

When melam is boiled with muriatic acid it dissolves completely, and the liquid, besides ammonia, contains another substance, to be noticed afterwards. Dilute sulphuric acid acts like muriatic acid; but concentrated sulphuric acid forms together with ammonia another product, very similar to the preceding, but differing in its composition and its properties.

If we boil melam in a moderately-concentrated solution of potash till it disappears completely, and evaporate the solution, we observe, when the concentration has been carried to a certain point, the

* This acid is described in the *Chemistry of Inorganic Bodies* (vol. ii. p. 225) under the name of *cyanous acid;* and in p. 208 of this work under the name *cyanoric acid.* It was supposed at first to contain no hydrogen. But was shown by Wöhler and Liebig to contain a little of that principle.

formation of brilliant plates, the quantity of which augments as the liquid cools. The liquid which swims over these crystals retains scarcely a trace of this substance. Neutralized by acids or by an addition of sal ammoniac, it gives a thick white gelatinous precipitate. This substance is identical with that formed when melam is treated with muriatic acid. The brilliant crystals constitute the substance called *melamin*.

If we merely add sal ammoniac to the solution without neutralizing it, and then evaporate, long, and very fine needles are deposited. This is the same salt as is obtained when melam, or the yellow substance remaining after the ignition of melam, is treated with potash.

It appears from the experiments of Knapp, which were made with great precision, that when melam is dissolved in concentrated nitric acid, it is converted into *ammelide* and *ammonia*. Dilute nitric acid forms with it ammelin and melamin. The ammelide is slowly converted into cyanuric acid.

From 1 atom of amelide	C^6	$H^{4\frac{1}{2}}$	$Az^{4\frac{1}{2}}$	O^3
Take $1\frac{1}{2}$ atoms ammonia		$H^{4\frac{1}{2}}$	$Az^{1\frac{1}{2}}$	
	C^6		Az^3	O^3
Add 3 atoms water		H^3		O^3
We have 1 atom cyanuric acid	$= C^6$	H^3	Az^3	O^6*

SECTION IV.—OF MELAMIN.†

To prepare this substance, we take the well-washed residue of the distillation of 2 lbs. of sal ammoniac, and 1 lb. of sulphocyanodide of potassium; add to it 2 ounces of fused hydrate of potash dissolved in 3 or 4 lbs. of water, and keep the whole in a boiling temperature till the liquid is quite clear, which in general takes place after three days boiling. During the ebullition, the colour of the residue changes to yellowish-white; the liquid becomes milky, and its consistence increases. The liquid evaporated must be replaced from time to time, by adding new quantities of solution of potash, of the same strength as that employed at first. When the liquid has become clear, we filter and evaporate at a gentle heat till the brilliant plates begin to appear. We then allow the liquid to cool slowly, wash the crystals and purify them completely by repeated crystallizations.

The crystals of pure melamin are octahedrons with rhomboidal bases having angles of about 75° and 105°. They are colourless and have the vitreous lustre. They are not altered by exposure to the air, and contain no water of crystallization.

Melamin is very little soluble in cold water; but boiling water is a better solvent. It is insoluble in alcohol and ether. When heated the crystals decrepitate and melt into a transparent liquid which concretes on cooling into a crystalline mass. When the heat is

* Ann. de Chim. et de Phys. lxiv. 239; or Ann. der Pharmacie, xxi. 241.

† Liebig, ibid. lvi. 23.

farther increased, the melamin rises along the inside of the tube without subliming. At a red heat it is decomposed, giving out ammonia, and there remains a lemon-yellow residue, which in a still higher temperature is decomposed into cyanogen and azote, without leaving any residue whatever.

Melamin combines with all the acids, and forms with them well characterized salts. They all without exception, possess slightly acid characters; but they form also disalts which are perfectly neutral. When it is heated with a solution of sal-ammoniac, ammonia is disengaged, and the melamin combines with the muriatic acid. The sulphate and nitrate of copper, the salts of zinc, of iron, and of manganese are decomposed by a solution of melamin in water, and the oxides are precipitated. In general it combines with a portion of the acid and base, and forms a double disalt.

Melamin contains no oxygen. When fused with potassium, ammonia is disengaged with the appearance of light and a fusible salt formed soluble in water, which possesses the characters of the compound formed by means of mellon and potassium under the same circumstances. When melamin is fused with hydrate of potash, cyanate of potash is formed; if the melamine be in excess, we obtain also mellonet of potassium.

When melamin is decomposed by oxide of copper, and the gaseous products collected, they consist of equal volumes of carbonic acid and azotic gas. M. Liebig found the constituents to be

Carbon	28·64 or 6 atoms =	4·5	or per cent.	28·57
Hydrogen	4·82 or 6 atoms =	0·75	— —	4·76
Azote	66·54 or 6 atoms =	10·5	— —	66·67
	100·00	15·75		100·00

It is obvious that any equal multiples of 1 atom carbon + 1 atom hydrogen + 1 atom azote would equally correspond with the analysis of Liebig. The only sure way of determining the true composition is to determine the proportion of this base necessary to saturate an atom of acid. We shall find afterwards that the analysis of oxalate of melamin indicates 15·75 for the atomic weight of melamin.

When melamin is strongly heated with concentrated sulphuric acid it is decomposed without becoming black. Ammonia is disengaged and a new substance formed which remains in solution in the acid. It is the same substance which is formed when mellon is heated in the same acid.

The dilute acids combine with melamin without altering it. For sulphuric acid it has a pretty strong affinity. The presence of even a small quantity of this acid is immediately indicated by a crystalline precipitate, which is abundant and very little soluble in cold water, but more soluble in hot water, and when the solution cools, this substance crystallizes in fine and short needles.

We easily obtain the nitrate of melamin by adding nitric acid to a hot solution of melamin, in water, till the liquid is strongly acid. When the liquid cools, the nitrate of melamin crystallizes in silky

needles, not altered by exposure to the air. They may be dissolved and crystallized a second time without decomposition. When this salt is burnt it gives out carbonic acid and azotic gases, in the proportions : : 6 : 7. Showing that it contains 6 atoms of carbon, and 7 of azote.

Oxalate of melamin is more soluble in water than the nitrate. When analyzed, it yielded carbonic acid and azotic gases in the proportions : : 8 : 6. Showing the constitution of melamin. The atoms of carbon in the oxalate are 8, and those of azote 6. Besides the 6 atoms of carbon in the melamin there are 2 atoms in the oxalic acid. In the nitrate there are 6 atoms of azote from the melamin, and one atom from the nitric acid making together 7.

M. Liebig, analyzed oxalate of melamin, and obtained

Carbon	27·63 or 8 atoms =	6	or per cent.		28·08
Hydrogen	3·73 or 7 atoms =	0·875	—	—	4·09
Azote	48·67 or 6 atoms =	10·5	—	—	49·12
Oxygen	19·97 or 4 atoms =	4·00	—	—	18·71
	100·00	21·375			100·00

Now this is equivalent to

1 atom melamin .	C^6	H^6	Az^6
1 atom oxalic acid .	C^2		O^3
1 atom water . .		H	O
	C^8	H^7 Az^6	O^4

The *acetate of melamin* is very soluble in water, and crystallizes in large flexible rectangular plates.

The *phosphate of melamin* dissolves readily in boiling water. If the solution be concentrate it solidifies on cooling into a white matter composed of concentric needles.

The *formate* of melamin is easily soluble and crystallizable.

If we add a hot solution of melamin to nitrate of silver, a white crystalline precipitate falls which increases as the liquid cools. It may be crystallized without decomposition. It was analyzed by M. Liebig, and found composed of

1 atom nitric acid . . .	6·75
1 atom melamin . . .	15·75
1 atom oxide of silver . .	14·5
	37·0

SECTION V.—OF AMMELIN.*

It was mentioned before, that when melam is dissolved in caustic potash, melamin precipitates in plates, and another substance remains in solution. This substance is *ammelin*. If we saturate the potash with acetic acid, the ammelin falls down. It is precipitated also by carbonic acid, and by carbonate of ammonia. We obtain a very bulky white precipitate, which is not in the least crystalline.

* Liebig, Ann. de Chim. et de Phys. lvi. 31.

If it be washed, and then dissolved in nitric acid, and the solution concentrated, we obtain long four-sided prisms, either white, or having a slight shade of yellow. If we dissolve these crystals in water, acidulated with nitric acid, and precipitate by caustic ammonia, or carbonate of ammonia, we obtain ammelin in a state of purity.

It has a fine white colour, and when precipitated by ammonia, it has a crystalline texture. It is insoluble in water, alcohol, and ether; but soluble in the fixed caustic alkalies, and in most of the acids. When heated it gives a crystalline sublimate, and ammonia; it becomes lemon-yellow, and if we continue to heat it, decomposition takes place, it being transformed into cyanogen and azote, without leaving any residue.

With the acids it behaves as a base; but its alkaline properties are not so well characterized as those of melamin. With the principal acids it forms salts which crystallize readily, but which are partly decomposed by water. This liquid dissolves an acid compound, and leaves ammelin under the form of a white powder. Ammelin does not decompose the ammoniacal salts by ebullition; but with many of the other salts it forms double subsalts similar to those of melamin.

When ammelin is burnt with oxide of copper, carbonic acid and azotic gases are given off in the proportion : : 6 : 5.

M. Liebig analyzed ammelin, by means of oxide of copper, and obtained

Carbon	28·064 or 6 atoms = 4·5	or per cent.	28·34
Hydrogen	3·966 or 5 atoms = 0·625	— —	3·94
Azote	54·062 or 5 atoms = 8·75	— —	55·11
Oxygen	13·908 or 2 atoms = 2·00	— —	12·61
	100·000	15·875	100·00

Nitrate of ammelin is partially decomposed by water. Hence, when we wish to crystallize this salt anew, we ought to add to the solution a little nitric acid. Ammelin, or its nitrate, may be dissolved in concentrated nitric acid, boiled and evaporated without decomposition. But when nitrate of ammelin is heated by itself, it is easily decomposed. We obtain nitric acid, nitrate of ammonia, protoxide of azote and water. There remains a white substance, which dissolves readily in acids, without forming salts with them.

Nitrate of ammelin was analyzed by M. Liebig, and found composed of

1 atom ammelin . . .	15·875
1 atom nitric acid . . .	6·75
1 atom water . . .	1·125
	23·75

Nitrate of ammelin gives, with nitrate of silver, a precipitate of the same nature as that produced by melamin. It is white, crystalline, does not lose water when heated, and when burnt with oxide of copper, furnishes carbonic acid and azotic gas, in the same proportion as the simple nitrate.

It was analyzed by Liebig, who found it composed of

1 atom nitric acid . . .	6·75
1 atom ammelin . . .	15·875
1 atom oxide of silver . .	14·50
	37·125

Knowing the composition of melamin and of ammelin, it is easy to explain their formation in the decomposition of melam. 2 atoms melam, and 2 atoms water, became obviously 1 atom melamin, + 1 atom ammelin.

For 2 atoms melam . .	$C^{12}\ H^{9}\ Az^{11}$
2 atoms water . .	$H^{2}\ O^{2}$
	$C^{12}\ H^{11}\ Az^{11}\ O^{2}$
1 atom melamin .	$C^{6}\ H^{6}\ Az^{6}$
1 atom ammelin .	$C^{6}\ H^{5}\ Az^{5}\ O^{2}$
	$C^{12}\ H^{11}\ Az^{11}\ O^{2}$

When melam is boiled with muriatic acid, there are formed ammelin and ammonia.

1 atom melam . .	$C^{6}\ H^{4\frac{1}{2}}\ Az^{5\frac{1}{2}}$
2 atoms water . .	$H^{2}\ O^{2}$
	$C^{6}\ H^{6\frac{1}{2}}\ Az^{5\frac{1}{2}}\ O^{2}$
Subtract $\frac{1}{2}$ atom ammonia	$H^{1\frac{1}{2}}\ Az^{\frac{1}{2}}$
Remain of ammelin .	$C^{6}\ H^{5}\ Az^{5}\ O^{2}$

When dry ammelin and hydrate of potash are fused together, the matter swells much, ammonia is disengaged, together with the vapour of water. When the action is at an end, we have a transparent liquid, very fluid, and which, on cooling, concretes into a crystalline mass. The salt thus formed is pure cyanate of potash. If to the melted potash we add a small excess of ammelin, the salt is quite neutral, and dissolves readily in water.

The solution is decomposed by acids in the manner known. By evaporation, ammonia is disengaged, and carbonate of potash remains.

It is easy to explain the formation of cyanic acid by the decomposition of ammelin fused with potash. 1 atom of ammelin, and 1 atom of water, are converted into 3 atoms cyanic acid, and 4 atoms ammonia.

1 atom ammelin .	$C^{6}\ H^{5}\ N^{5}\ O^{2}$
1 atom water . .	$H^{1}\ O$
	$C^{6}\ H^{6}\ N^{5}\ O^{3}$
Subtract 2 ammonia .	$H^{6}\ N^{2}$
Remain . . .	$C^{6}\ N^{3}\ O^{3}$

which make 3 atoms cyanic acid.

SECTION VI.—OF AMMELIDE.*

If we add alcohol to a solution of melam or melamin, in concentrated sulphuric acid, we obtain a thick white precipitate. Simply washing it with water, frees it from all acid. The sulphuric acid contains ammonia. We obtain the same substance, if we heat nitrate of ammelin till the soft and pasty mass becomes solid. We obtain it also by boiling melamin in concentrated nitric acid, till it is entirely dissolved.

If we boil impure melam in dilute sulphuric acid, it dissolves, and if we evaporate gently, we obtain crystals of sulphate of ammelin. These, if we continue to concentrate, or if we boil the liquid, are redissolved, and undergo decomposition, the new substance, to which Liebig has given the name of *ammelide*, is formed, together with a quantity of ammonia. It may be precipitated from its solutions by the alkaline carbonates, or by alcohol.

Ammelide is a white powder, which possesses no alkaline properties. It dissolves indeed easily in acids, and we obtain, especially with nitric acid, crystals. But alcohol and water deprive them entirely of their acid.

Ammelide was analyzed by Liebig, by means of oxide of copper. He obtained carbonic acid and azotic gas in the proportions : : 6 : 4·5. He found the constituents as follows :—

Carbon	27·54 or 6	atoms =	4·5	or per cent.	28·24
Hydrogen	3·61 or $4\frac{1}{2}$	atoms =	0·5625	— —	3·53
Azote	47·84 or $4\frac{1}{2}$	atoms =	7·875	— —	49·41
Oxygen	21·01 or 3	atoms =	3·000	— —	18·82
	100		15·9375		100·00

Or, we might represent the constituents by the following formula, which is much simpler :—

4 atoms carbon . . .	= 3·0
3 atoms hydrogen . .	= 0·375
3 atoms azote . . .	= 5·25
2 atoms oxygen . . .	= 2·00
	10·625

It is obvious that the ratios are the same as in the preceding.

M. Knapp,† to determine the constitution of ammelide with as much accuracy as possible, dissolved it in dilute hot nitric acid, and added an excess of hot nitrate of silver. The solution remained clear; but ammonia (not added in excess) threw down a white curdy precipitate, which was ammelide, combined with oxide of silver. It was washed and dried. Being analyzed in the usual way, it gave

* Liebig, Ann. de Chim. et de Phys. lvi. 37.
† Ann. de Chim. et de Phys. lxiv. 248.

Silver	45·84
Carbon	15·40
Hydrogen	1·40
Azote	26·86
Oxygen	10·50
	100·00

These numbers lead to the following formula:—

1	atom silver	13·5	or per cent.	46·05
6	atoms carbon	4·5	— —	15·36
$3\frac{1}{2}$	atoms hydrogen	0·4375	— —	1·49
$4\frac{1}{2}$	atoms azote	7·875	— —	26·86
3	atoms oxygen	3	— —	10·24
		29·3125		100

But one of the atoms of oxygen was in combination with the silver. Hence the constituents of ammelide must be

6	atoms carbon . .	= 4·5
$3\frac{1}{2}$	atoms hydrogen . .	= 0·4375
$4\frac{1}{2}$	atoms azote . . .	= 7·875
2	atoms oxygen . .	= 2·000
		14·7125

So that the atomic weight of ammelide must be 14·7125.

The salt, before analysis, was dried in a temperature of 410°.

Liebig remarks, that in the transformations which melamin undergoes, its alkaline properties diminish in proportion as the oxygen with which it enters into combination increases. Something similar may be observed in the vegetable alkaloids. Narcotin, solanin, and some others, whose alkaline properties are not very decided, are distinguished from the strong alkaloids by a greater dose of oxygen.

SECTION VII.—OF CHLORIDE OF CYANOGEN.*

During the decomposition of sulphocyanodide of potassium, by means of dry chlorine gas, there distils, besides chloride of sulphur, *chloride of cyanogen*, which, towards the end of the distillation, when the fire is increased, is deposited in the neck of the retort in long transparent needles. Another portion is dissolved in the chloride of sulphur. We obtain altogether from 4 to 5 per cent. of chloride of cyanogen. It is freed from a little chloride of sulphur with which it is mixed, by subliming it in a vessel through which a dry current of chlorine gas is passing.

When thus purified, it is in very brilliant needles and plates, which have a distinct smell of the excrements of mice.

This chloride was analyzed by Liebig with great care. To determine the quantity of chlorine which it contained, he dissolved the chloride of cyanogen in alcohol, added ammonia to the solution, and boiled it, mixed with a great deal of water, till all the spirit of

* Liebig, Ann. de Chim. et de Phys. lvi. 46.

wine was volatilized. He then added an excess of nitric acid, and precipitated by nitrate of silver.

100 parts of chloride of cyanogen gave 230·72 parts of chloride of silver, equivalent to 57·68 of chlorine. Hence chloride of cyanogen is composed of

Chlorine . .	57·68 or 1	atom
Cyanogen . .	42·32 or 1·01	atom
	100·00	

Thus Liebig, by this analysis, has confirmed the original determination of Gay-Lussac.

SECTION VIII.—OF CYANAMIDE.*

If we sprinkle ammonia on crystallized chloride of cyanogen, and heat gently, it loses its crystalline aspect, and is reduced to a white powder. This substance is slightly soluble in boiling water, and precipitates in white flocks when the liquid cools. We obtain the same substance if we pass ammoniacal gas through chloride of cyanogen in powder, and placed in a horizontal tube. At first a mutual decomposition takes place with the disengagement of heat. Towards the end of the process we must apply heat to render the decomposition complete. We obtain a white powder with a slight shade of yellow, which may be completely freed from sal ammoniac by washing it in cold water. This substance is *cyanamide*.

It contains chlorine, which cannot be separated by water, nor by boiling with caustic ammonia. When it is heated, a crystalline substance sublimes, containing all the chlorine, and there remains a lemon-yellow residue, which is decomposed at a red heat into cyanogen and azote.

The action of cyanamide on caustic potash is remarkable. It dissolves with difficulty, but with the disengagement of ammonia. If we saturate the clear solution with acetic acid, no cyanurate of potash crystallizes, as one would have it expected to do; but there precipitates a substance in white flocks, which, as is evident from the disengagement of ammonia, must differ in its composition from cyanamide.

When cyanamide is burnt with oxide of copper, it gives a mixture of carbonic acid and azotic gas in the proportion : : 5 : 4.

Liebig found farther, that 527 parts of cyanamide furnished, when decomposed by oxide of copper, 156 parts water, and 551 parts of carbonic acid.

From these data it is easy to determine the quantity of carbon, hydrogen, and azote contained in 100 parts of cyanamide. What is wanting to complete the 100 parts is, of course, chlorine. But if we calculate from these data, we obviously obtain nothing else than a mixture of two different substances.

When cyanamide was heated to 244° in a glass vessel, the inside of the vessel became covered with brilliant crystals destitute of

* Liebig, Ann. de Chim. et de Phys. lvi. 51.

smell, although the cyanamide itself did not appear volatile. Liebig thinks it not unlikely that the cyanamide, such as he analyzed it, was a mixture or a compound of

1 atom cyanamide . . .	$C^4 H^4 Az^4$
1 atom chloride of cyanogen .	C^2 Az Chl
Making	$C^6 H^4 Az^5$ Chl

For this last is the formula deducible from the analysis made by Liebig.

SECTION IX.—OF THE POTASH SALT.*

When melam, ammelin, ammelide, and cyanamide, are heated to redness, they undergo decomposition, and a lemon-yellow substance remains, which dissolves completely when boiled in potash.

When this solution is evaporated, it concretes into a crystalline mass, composed of long and very fine needles. We obtain the same salt of potash, if we dissolve, in a solution of potash, mellon, or the yellow substance which results from the decomposition of sulphocyanodide of potassium by chlorine.

By repeated crystallizations, this salt may be obtained in colourless crystals. It is very soluble in water, but insoluble in alcohol. So that if we mix the aqueous solution with its own bulk of alcohol, the salt is precipitated in small white needles.

This salt possesses strongly marked alkaline properties. It contains water of crystallization, melts when heated, gives out ammonia without blackening, and leaves pure cyanate of potash. When dissolved in water, if we add some drops of acetic acid, and then chloride of barium, there is formed immediately, or very soon, a crystalline precipitate in fine needles of supercyanurate of barytes.

If we dissolve it in concentrated muriatic or nitric acid, we obtain, on cooling, a number of crystals of pure cyanuric acid. If we expose a dilute solution of the salt to the air, so that it may absorb carbonic acid, or if we neutralize it cautiously, a white precipitate falls, and the filtered liquid contains cyanurate of potash.

We see that the yellow substance, when boiled with potash, gives the same products as when treated with nitric acid; namely, cyanuric or cyanilic acid. But there is formed, at the same time, a small quantity of another salt, which conceals the existence of the cyanurate by mixing with it.

M. Liebig has analyzed this salt with care, and has concluded, from his experiments, that it is a mixture of two combinations in very different proportions. He obtained

Carbon . .	33·73 or 5	atoms
Hydrogen . .	1·11 or 1	atom
Azote . . .	42·98 or 3	atoms
Oxygen . .	22·18 or $2\frac{1}{2}$	atoms
	100·00	

* Liebig, Ann. de Chim. et de Phys. lvi. 54.

He thinks that it may be a mixture of mellonide of potassium, and cyanodide of potash.

SECTION X.—OF NITROSULPHURIC ACID.

This acid was discovered by M. Pelouze, in 1835, though the first experiments which led to its discovery were made by Davy, in 1799. He observed that deutoxide of azote is absorbed by a mixture of potash or soda, with an alkaline sulphite, and that when the new salt formed, comes in contact with an acid, abundance of protoxide of azote is disengaged.* M. Pelouze observed, that if deutoxide of azote be cooled down to 5° or to —4°, and placed in contact with a solution of sulphite of ammonia, cooled down to the point at which it begins to congeal, and if we agitate occasionally, the gas is completely absorbed, and a new salt is formed. This salt undergoes spontaneous decomposition when heated up to 32°, or to a higher temperature, being converted into sulphate of ammonia, and protoxide of azote. The bulk of the protoxide of azote evolved, being just one-half of that of the deutoxide of azote absorbed.

If we make a concentrated solution of sulphite of ammonia, and mix it with five or six times its bulk of liquid ammonia, a current of deutoxide of azote may be passed through it for hours, without any spontaneous decomposition taking place. Fine crystals of the same salt are gradually deposited. When these crystals are dried, they may be kept unaltered in a well-stopped bottle.† M. Pelouze has distinguished the acid combined in these crystals with ammonia, by the name of *nitrosulphuric acid*.

If we place a mixture of 2 volumes of deutoxide of azote, and 1 volume of sulphurous acid gas, in contact with caustic potash, the whole gas is gradually absorbed. But the absorption is not complete if any other proportions of the gases be employed. When we examine the salt formed, we find that it contains no sulphurous acid, for red sulphate of manganese is not discoloured by it. Solution of indigo in sulphuric acid is not discoloured by it, showing the absence of nitric or nitrous or hyponitrous acids. The precipitate formed in the salt by any soluble salt of barytes, when well washed with potash, is soluble in nitric acid, showing the absence of sulphuric acid.

It is obvious from these facts, that nitrosulphuric acid is a compound of

	2 atoms deutoxide of azote	$Az^2\ O^4$
	1 atom sulphurous acid .	$S\ O^2$
		$S\ Az^2\ O^6$
or of	1 atom sulphur . . .	= 2
	2 atoms azote . . .	= 3·5
	6 atoms oxygen . . .	= 6
		11·5

So that its atomic weight is 11·5.

* Davy's Researches, p. 258. † Pelouze, Ann. de Chim. et de Phys. lx. 151.

Nitrosulphate of ammonia, is a white salt, having a sharp and slightly-bitter taste, quite different from that of the sulphites. It is neutral, crystallizes in oblique four-sided prisms, generally flat and variously terminated. It is insoluble in alcohol, but dissolves readily in water, and is decomposed into sulphate of ammonia, and protoxide of azote, with so much the greater rapidity the higher the temperature is. Alcohol precipitates this salt from its aqueous solution. When heated up to 230°, it is decomposed with an explosion, protoxide of azote being given out with great rapidity.

All the acids disengage protoxide of azote, and cause it to pass into sulphate of ammonia. Even an addition of caustic ammonia does not prevent this salt from undergoing spontaneous decomposition, though it renders that decomposition much slower. Spongy platinum, oxide of silver, metallic silver, charcoal powder, oxide of manganese, &c., decompose it as they do binoxide of hydrogen, protoxide of azote flying off, and sulphate of ammonia remaining. These bodies themselves undergo no alteration.

When solutions of chloride of mercury, sulphates of zinc and copper, persulphate of iron, protonitrate of mercury, chloride of chromium, or of nitrate of silver previously cooled by a freezing mixture, were dropt into a solution of nitrosulphate of ammonia, a strong effervescence took place, protoxide of azote being disengaged, and sulphate of ammonia remaining. With acetate of lead there is an effervescence, and sulphate of lead formed. The presence of a quantity of alkaline solution prevents these decompositions.

This salt is composed of

1 atom nitrosulphuric acid .	11·5
1 atom ammonia . . .	2·125
1 atom water . . .	1·125
	14·750

Nitrosulphate of potash is white, very soluble in water, insoluble in alcohol; destitute of smell, having a slightly bitter taste and neutral. It crystallizes in irregular six-sided prisms, not unlike those of nitre. At 230°, it undergoes no change and loses no weight. At 266°, it is destroyed, but not in the way that nitrosulphate of ammonia is. Deutoxide of azote is disengaged, and sulphate of potash remains. The acids, even the weakest, disengage deutoxide of azote from it. Spongy platinum, and the other substances mentioned above, decompose it, protoxide of azote being disengaged, and sulphate of potash remaining. But the decomposition is much slower than with nitrosulphite of ammonia.

This salt may be dissolved in boiling water without decomposition. It is anhydrous, and consists of

1 atom nitrosulphuric acid .	11·5
1 atom potash	6
	17·5

Nitrosulphate of soda is much more soluble than the preceding salt, but in other respects resembles it.

The attempts made by M. Pelouze to obtain nitrosulphuric acid in a separate state, were unsuccessful.

When 2 volumes of deutoxide of azote, and 1 volume of sulphurous acid were left in a tube with a little water, sulphuric acid was gradually formed, and 1 volume of protoxide of azote remained in the gaseous state.

DIVISION II.

OF THE PARTS OF PLANTS.

We have in the preceding Division enumerated and described the different *ingredients* of plants, so far as they have been hitherto investigated. We now undertake a more difficult task, namely, to explain the composition of each vegetable organ in all the numerous families of plants which constitute the vegetable kingdom. This task, indeed, in the present state of vegetable chemistry, cannot be fulfilled. By far the greater number of plants have never been examined at all; and even of those which, from their medicinal virtues or nutritive qualities, have attracted the attention of chemists, only particular organs have been analyzed, while the rest have been neglected as unworthy of notice. Nothing, therefore, either resembling a complete view, or an exact arrangement, is to be looked for in this Division. I shall satisfy myself with stating the most important facts hitherto discovered respecting the composition of plants, as far as I am acquainted with them, under the seventeen following heads:

1 Sap
2 Peculiar juices
3 Gases
4 Barks
5 Roots
6 Bulbs
7 Wood
8 Pith
9 Herbaceous plants
10 Leaves
11 Flowers
12 Fruits and seeds
13 Ferns
14 Lichens
15 Mushrooms
16 Fuci
17 Diseases.

CHAPTER I.

OF THE SAP OF PLANTS.

It is the general opinion of physiologists, that plants receive a considerable part of their nourishment by the root; that it enters into them in a liquid state, and passes up in proper vessels towards the leaves. This liquid is distinguished by the name of *sap*. In the spring when the buds begin to expand themselves into leaves, if we break off the extremity of a branch, or cut into the wood of a tree, this sap flows out, and may be obtained in considerable quantities. It was first examined by Dr Hales; but chemical analysis had not made sufficient progress in his time to enable him to ascertain its constituents. Deyeux and Vauquelin have more recently analyzed the sap of different trees. To them we are indebted for most of the

facts known respecting this liquid. A few additional facts have been ascertained by John.

The sap in all the vegetables hitherto examined is nearly as liquid as water. It always contains an acid, sometimes free, but more commonly combined with lime and potash. Various vegetable principles are also present: of these sugar is the most remarkable, and mucilage. Sometimes albumen and gluten, and sometimes tannin, can be detected. When left to itself, the sap soon effervesces and becomes sour; or even vinous, when the proportion of sugar is considerable.

Hitherto the sap of a few species of trees only has been examined. We are not in possession of any means of collecting the sap of the inferior orders of plants. The expressed juices of a considerable number of vegetables, indeed, have been prepared for medicinal purposes; but these are not sap, but a collection of all the liquid substances which the plant contained. At present, then, it is not possible to present a general view of the properties of sap. The following are the particular species which have been examined:—

1. *Sap of the Elm, ulmus campestris.* Vauquelin collected three different specimens of the sap of this tree; the first portion towards the end of April, the second in the beginning of May, and the third about the end of May. It had a reddish-brown colour; its taste was sweet and mucilaginous; and it scarcely altered the colour of the infusion of litmus. Ammonia, barytes, and lime water threw down a copious yellow-coloured precipitate, which dissolved with effervescence in acids. Oxalic acid and the nitrate of silver throw down a white precipitate. Diluted sulphuric acid occasions a brisk effervescence, and disengages the odour of acetic acid. Chlorine destroys the colour of the sap, and throws down a brown precipitate.

Alcohol produces a flaky precipitate. When evaporated by a gentle heat, a pellicle forms on the surface; brown flakes precipitate, and an earthy matter is deposited on the sides of the vessel. The earthy matter was a mixture of carbonate of lime and vegetable substance. The liquid, after depositing these bodies, and being evaporated to $\frac{9}{10}$ths of its original bulk, contained a considerable portion of acetate of potash.

1039 parts of this sap were composed, according to Vauquelin's analysis, of

Water and volatile matter .	1027·904
Acetate of potash . .	9·240
Vegetable matter . .	1·060
Carbonate of lime . .	0·796

The vegetable matter was partly extractive and partly mucilaginous.*

On analyzing the same sap somewhat later in the season, M. Vauquelin found the quantity of vegetable matter a little increased, and that of the carbonate of lime and acetate of potash diminished. Still later in the season the vegetable matter was farther increased, and the other two ingredients farther diminished. The carbonate

* Ann. de Chim. xxxi. 20.

of lime was held in solution by carbonic acid, of which there existed a considerable excess in the sap. It is to this acid gas that the air bubbles, which so often accompany the sap as it issues from the tree, is owing.*

2. *Sap of the Beech, fagus sylvatica.* Vauquelin collected two different specimens of this sap; the first in the end of March, the second about the end of April. It had a reddish-brown colour, and a taste similar to the infusion of tan. It slightly reddened vegetable blues. Barytes, ammonia, carbonate of potash, and oxalate of ammonia, occasion precipitates in it; chlorine throws down yellow flakes; sulphuric acid blackens it, and disengages the odour of acetic acid; sulphate of iron strikes a black, and glue throws down a copious whitish precipitate. When gently evaporated to dryness, it leaves a brown extract amounting to about $\frac{1}{43}$ of its weight, ductile while hot, but brittle when cold, and having the smell and somewhat of the taste of new baked bread. It absorbs moisture from the atmosphere, and increases in weight about $\frac{1}{7}$th. Lime disengages ammonia, and sulphuric acid acetic acid, from this extract. Alcohol dissolves only a small part of it. This sap contained the following ingredients:—

Water
Acetate of lime with excess of acid
Acetate of potash
Gallic acid
Tannin
A mucous and extractive matter
Acetate of alumina.

It contained, besides, a colouring matter, which may be fixed on cotton and linen by means of alum, and dyes them of a fine solid reddish-brown colour.†

3. *Sap of the Hornbeam, carpinus sylvestris.*‡ Three specimens of this sap were collected by Vauquelin during the months of March and April. It was limpid, and its colour was whitish; its taste slightly sweet, and its smell analogous to that of whey. Barytes throws down from it a copious white precipitate, soluble in muriatic acid. Carbonate of potash likewise throws down a precipitate soluble in acids with effervescence. Sulphuric acid deepens the colour, and evolves the odour of vinegar. Oxalic acid throws down a copious precipitate, and nitrate of silver gives the solution a fine red colour. 3918 parts, when distilled, left an extract of a reddish-yellow colour, amounting to 8·279 parts. It had a sharp taste, and attracted humidity from the air.

When the extract is digested in alcohol, about the half of it dissolves. This portion consists of extractive, a saccharine matter, and acetate of potash. The residue, which is soluble in water, consists of mucilaginous matter, acetate of lime, and a colouring substance.

* See Coulomb, Jour. de Phys. xlix. 392. † Ann. de Chim. xxxi. 26.
‡ I presume the carpinus betulus is meant.

When this sap was left exposed to the air in an open glass vessel, it became milky, disengaged carbonic acid, acquired a spirituous smell and taste, and its acidity increased. After some weeks this odour was dissipated, and carbonic acid was no longer extricated. Its acidity continued still to increase, white flakes fell to the bottom, and the liquid became transparent. After 50 days the acidity was found diminished, a mucous pellicle formed on the surface, which became at last blackish brown, and the liquid had only a mouldy taste. In a close bottle the sap never became transparent; and when the bottle was opened after three months, the air which it contained was found converted into azote and carbonic acid. The liquid had a very strong taste of vinegar.*

4. *Sap of the Birch, betulus alba.* The sap of this tree is colourless; it has a sweet taste; reddens vegetable blues. Neither ammonia, alcohol, nor chlorine, produce any change upon it. Barytes and lime throw down a precipitate which dissolves in muriatic acid. Hydrosulphurets, sulphate of iron, and glue, produce no effect. Oxalic acid throws down a white precipitate. Sulphuric acid disengages the odour of vinegar. Nitrate of silver strikes a red colour. When evaporated to about $\frac{1}{4}$th, it lets fall a reddish-brown powder insoluble in water. When 3918 parts of the sap were evaporated to dryness, they left 34 parts of brown extract. This had an agreeable taste, attracted moisture from the atmosphere, and was almost completely soluble in alcohol. When this extract is dissolved in water, and mixed with yeast, it ferments, and the fermented liquor yields a considerable portion of alcohol; it yields also a considerable portion of vinegar. Vauquelin did not succeed in his attempts to obtain crystallized sugar from this sap; but he ascertained that it contained a portion of extractive which dyes wool of a brownish-yellow colour. Acetate of lime and of alumina were also present, and probably also acetate of potash.†

More lately Dr John has made a few experiments on the sap of the birch. He found it transparent, colourless, destitute of smell, and scarcely sweetish. Its specific gravity was 1·004. One portion of birch sap which had been frozen did not alter vegetable blues; but another portion which had not been frozen reddened them. From 1730 grains of sap he obtained only 4 grains of sugar. He found in it likewise a little carbonate of lime, which precipitated of its own accord when the sap was left exposed to the air. He thought likewise that it contained traces of a tartrate, some gummy matter, and some albumen.‡

5. *Sap of the Yoke Elm.* This sap has a bitter taste. When evaporated to dryness it leaves a brown extract, in which crystals of nitrate of potash are gradually formed. This extract was scarcely soluble in alcohol. It gave traces of the presence of acetate of potash and acetate of lime.§

6. *Sap of the Vine, vitis vinifera.* This sap was examined by Dr

* Ann. de Chim. xxxi. 31. † Ibid. 36.

‡ Chemische Untersuchungen, ii. 4. § Ann. de. Chim. xxxi. 38.

Prout. It had the whitish appearance of common river water. Its taste was sweetish but not rough. It did not alter litmus paper, nor did its specific gravity differ from that of pure water. Potash and ammonia gave it a fine red colour, and threw down red flocks readily dissolved by acetic acid. It was slightly precipitated by oxalate of ammonia, ferrocyanate of potash, nitrate of silver, and subacetate of lead. 2300 parts of it when evaporated left only 1 part of residuum, half of which was carbonate of lime and the remainder a peculiar vegetable matter, which was insoluble in alcohol. The sap had contained both carbonic and acetic acids, and likewise an alkali.* Several specimens of the sap of the vine were examined by M. Robiquet. He found in them carbonic acid, tartrate of lime, bitartrate of potash, and a mucilaginous and flocky matter, the vegeto-animal matter of Deyeux.†

7. *Sap of the common mapple, acer campestre.* The sap of this tree was examined by Professor Scherer, of Vienna. It has a milky aspect, a sweetish taste, and its specific gravity varies. It does not alter litmus or turmeric paper. It is precipitated by oxalate of potash, nitrate of silver, and barytes water; but not by muriate of barytes. When boiled it lets fall gluten in flocks. It yields when evaporated a salt with basis of lime possessing peculiar properties. The acid is destroyed by heat, and according to Scherer differs from every other vegetable acid. He therefore distinguishes it by the name of *aceric* acid. The acerate of lime is white, slightly translucent; has a weak acidulous taste, and is not altered by exposure to the atmosphere. 1000 parts of cold water dissolve 9 parts, and 1000 parts of boiling water 17 parts of this salt.‡

Boussingault has lately examined the sap of the *musa paradisica*. It is limpid like water. When left exposed to the air it lets fall red flocks. It stains linen, but loses this property by exposure to the air. It contains

1 Tannin
2 Gallic acid
3 Acetic acid
4 Common salt
5 Salts of lime, potash, and alumina.§

CHAPTER II.

OF THE PECULIAR JUICES.

The sap passes from the roots in peculiar vessels to the leaves, where it is altered by a process similar to that of digestion in animals, and formed into all the liquid substances requisite for the

* Annals of Philosophy, v. 109.
† Jour. de Pharmacie, xviii. 36.
‡ Schweigger's Jour. iv. 362.
§ Jour. de Pharmacie, xxii. 385.

purposes of the plant. These liquids flow from the leaves towards the root in appropriate vessels, and have received the name of the *peculiar juices* of vegetables. They differ very considerably from each other in different plants. They have all a certain degree of consistency, and always contain much more vegetable matter than the sap. In the present state of vegetable chemistry, an accurate detail of their properties cannot be attempted. Indeed, it is often difficult to procure them from any plants unmixed with the sap. They sometimes exude spontaneously, and may always be procured in smaller or greater quantity by incisions through the bark of the plants containing them. The following are the species of peculiar juices which have been hitherto attended to:—

1. *Milky juices.* Many plants, when wounded, emit a considerable quantity of a milky liquid, which may, in most cases, be considered as one of the peculiar juices of the vegetable from which it flows. These milky liquids gradually concrete into a solid matter, which has been distinguished by the name of *gum resin.* Several of these gum resins being employed in medicine, have been described among the vegetable principles, which constitute the First Division of this part of the system. This arrangement is, perhaps not, strictly speaking, accurate, as it has not been proved that these gum resins constitute peculiar vegetable principles. But it is convenient, and there is every resin to expect, that when these gum resins come to be more thoroughly examined, not a few new vegetable principles will be discovered among them. Indeed, this has been already verified in *opium*, to which, from peculiar circumstances, the attention of chemists has been particularly turned.

For an account of every thing at present known respecting the chemical nature of the gum resins, I refer to a preceding Chapter in this volume. A few remarks respecting some other milky juices not there alluded to, may be here subjoined.

The root of the *campanula rotundifolia* yields a milky juice, of a peculiar, and not unpleasant smell and taste. Children in some parts of Scotland collect the plant for the sake of this juice, which they suck with avidity. Its chemical properties have not been examined.

Humboldt mentions a tree which is a native of South America, which yields a milky juice, employed by the natives as a nourishing article of food. It is called in the country the cow-tree, and the milk of it, on standing, forms a film on the surface, resembling in its properties the curd of milk.*

This liquid, which exudes from the *galactodendron utile*, contains a peculiar vegetable principle, which I have distinguished by the name of *galactin*, and of which an account has been given in a preceding Chapter of this volume, while treating of the *fixed oils*.

The different species of *euphorbia* yield milky juices, which, of course, vary in their nature according to the species. In a preceding Chapter of this volume, while treating of the gum resins, an

* Ann. de Chim. et de Phys. vii. 182.

account has been given of *euphorbium*, which is the concrete milky juice of the *euphorbia officinalis*.

The milky juice of the *euphorbia myrtifolia*, a plant which grows in the West Indies, has been subjected to a chemical analysis by M. Ricord-Madianna,* who obtained

Water	73·2
Resin	1·8
Fixed oil containing euphorbin .	4·8
Mucilage :	0·3
Extractive	1·4
Cerin	11·6
Viscin	0·3
Lignin	0·2
Myricin	3·7
	97·3

The juice was treated repeatedly with alcohol, which was filtered and left for several days at rest. It deposited cerin. Evaporated, it left a yellow resin, soluble in ether. The remaining liquid was of the consistence of a syrup. Its smell was strong and disagreeable, and its taste burning. Ether dissolved a little resin from it. The residue stained paper like an oil. It would not dry. At first it rendered litmus paper green; but after being kept a month it reddened that paper. When treated with an alcoholic solution of potash, a kind of black soap was formed, soluble in water. When decomposed by binoxalate of potash, a blackish poisonous matter precipitated. This is the substance which M. Ricord-Madianna has called *euphorbin*.

The various species of euphorbia, so abundant in this country, yield a milky juice, which has a hot taste, analogous to that of pepper, but more acrid, and which continues for a long time in the mouth. When chlorine was poured into this juice, a very copious white precipitate fell down. This powder, when washed and dried, had the appearance of fine starch, and was not altered by keeping. It was neither affected by water nor alkalies. Alcohol, assisted by heat, dissolved $\frac{2}{3}$ds of it, which were precipitated by water, and had all the properties of resin. The remaining third part possessed the properties of the *woody fibre*. Mr Chaptal tried the same experiment on the juices of a great number of other plants, and he constantly found that chlorine precipitated from them *woody fibre*.†

Dr John made a set of experiments on the milky juice of the *euphorbia cyparissias*. Its colour is milk-white. It is opaque, and has a slippery feel. Its taste is at first sweetish with an impression of bitterness; and it leaves a feeling of burning heat in the mouth and on the tongue, which continues for some time. He found its constituents as follows:—

* Jour. de Pharmacie, xviii. 589. † Ann. de Chim. xxi. 285.

Water	77
Tartaric acid	—
Resin	13·80
Gum	2·75
Extractive	2·75
Albumen	1·37
Caoutchouc	2·00
Fixed oil	—
	99·67*

The different species of the poppy (*papaver*) and lettuce (*lacuta*) yield a milky juice, which possesses narcotic qualities, and is distinguished by a peculiar taste and smell. An account of the constitution of these juices, so far as they have been examined, has been given in a preceding Chapter of this volume, while treating of the gum resins.

The milky juice which exudes from the *jatropha elastica*, the *hevæa cauotchouc*, the *artocarpus integrifolia*, the *urceola elastica*, and from several other plants, gradually becomes inspissated when exposed to the air, and constitutes caoutchouc. All the facts hitherto ascertained respecting this curious milky juice, have been stated in a preceding Chapter of this volume, while treating of the neutral vegetable principles.

The juice of the papaw tree possesses properties which distinguish it from most others. According to the analysis of Vauquelin, its constituents resemble very closely the constituents of blood.

Dr John has made some experiments to ascertain the nature of the milky sap of the *Asclepias Syriaca*, which he was enabled to examine, from the plant being cultivated in the Botanic Garden at Berlin. The sap of this plant is milky, reddens vegetable blues, has a peculiar smell similar to that of narcotic substances. Its taste is sourish, peculiar, but not hot. Its constituents were as follows :—

Resin	26·5
Caoutchouc	12·5
Gluten	4
Extractive	4
Tartaric acid, Albumen } held in solution by water	73
	120·0†

The milky juice of the *Chondrilla Juncea*, a plant which vegetates abundantly in the neighbourhood of Frankfort, consists, according to the same chemist, of water, holding in solution mucilage, resin, and caoutchouc, in the following proportions :—

Mucilage	$\frac{1}{3}$
Resin	$\frac{1}{4}$
Caoutchouc	$\frac{1}{2}$‡

* Chemische Untersuchungen, i. 8. † Ibid. i. 20.
‡ Chemische Untersuchungen, ii. 1.

We have also, by Dr John, an analysis of the milky juice of the *Leontodon taraxicum*. He found in it

Water
Caoutchouc
Bitter extractive
A sweet tasted substance
A trace of resin
A trace of gum
A free acid
Muriate, phosphate, and sulphate of lime
Ditto of potash.*

The milky juice of the *Lactuca sativa* has also been examined, and found to contain,

1 A bitter principle, soluble in water and alcohol, insoluble in ether, not precipitated by salts of lead
2 Albumen
3 Caoutchouc
4 Wax
5 An acid
6 Chloride of calcium
7 Phosphate of lime
8 Potash
9 Gum and acetic acid†
10 Nitrate of ammonia.‡

2. *Mucilaginous Juices.* The peculiar juices of many plants are not milky, and some not distinguished by any strong taste or smell. In these mucilage seems to be the predominating matter.

The substance called *cambium*, too, if we may be allowed to consider it as a peculiar juice, since it is obviously different from the sap, is entirely mucilaginous. It makes its appearance, according to Mirbel, in all those parts of vegetables where new matter is to be formed, and seems necessary for all such formations, either as the matter employed in their formation, or as furnishing a proper bed for them to be formed in. It does not appear to be confined in vessels like the other juices.§

3. Some juices are intermediate between volatile oils and resins. These have been distinguished by the names of *turpentines* and *balsams*, and have been described in a preceding Chapter of this volume, while treating of *liquid resins*.

4. Other juices obtained by excision possess at first the properties of resins, or at least acquire them before they are brought into this country. Such, for example, are *tacamahac* and *mastich*, and the other resinous bodies described under the name of *resins*, in a preceding Chapter of this volume.

5. Some peculiar juices are composed almost entirely of tannin, or at least are characterized by containing a superabundance of

* Chemische Untersuchungen, iii. 1.
† Jour. de Pharmacie, xxii. 653. ‡ Ibid. xxi. 307.
§ Mirbel, Ann. de Mus. d'Hist. Nat. No. xl. p. 294.

that substance. Such, probably, are the juices of oak, sumach, and of most vegetables that yield abundance of the tannin principle. In some cases, it would seem that these juices exude spontaneously; though in general they are obtained by artificial means.

6. Some vegetables possess juices characterized by the great quantity of sugar which they contain. Such, for example, are the sugar-cane, the carrot, and the various species of beet. For it is surely more reasonable to consider the saccharine matter in these plants as belonging to the peculiar juices, than as confined to the sap.

7. Finally, the peculiar juices of some plants are characterized, by containing a considerable portion of saline matter. Thus the various species of sorel contain a notable quantity of binoxalate of potash, and several of the sedums malate of lime. In short, the peculiar juices of plants are nearly as numerous as the vegetable principles themselves; and when the fungi, algæ, lichens, and several other of the numerous inferior tribes of vegetables have been once examined, it cannot be doubted that the number will greatly increase.

Braconnot examined the juices of a number of plants, in order to ascertain the peculiar acids which they contained. The following is a short abstract of the results which he obtained:—*

The expressed juice of the *aconitum lycortonum* evaporated to dryness, and incinerated, leaves 0·01 of carbonate of potash. This juice contains a considerable proportion of citric acid, partly combined with potash and partly with lime. Perhaps also malic and acetic acids are present in the juice of this plant.

The juice of the *delphinum elatum*, the *ranunculus aconitifolius*, the *thalictrum flavum*, the *clematis recta* and *viticella*, likewise contains a quantity of citric acid like the preceding juice.

The juice of the *salvia sclarea* contains benzoic acid probably combined with potash.

The juice of the *ruta graveolens* contains malic acid combined with potash and with lime.

The juice of the *eupatorium cannabinum* contains an acid which appears to be the malic, mixed with some phosphoric.

The juice of the *nicotiana rustica* and *tabacum* contains malic acid combined with potash and lime.

The juice of the *mirabilis jalapa* contains nitric acid, muriatic acid, malic acid, and a little sulphuric acid chiefly combined with with potash.

The *spinacia oleracea* contains oxalates of lime, and of potash, malate, and phosphate of potash.

The *tropæolum majus* contains phosphoric acid, nitric acid, and malic acid united to lime and to potash.

The *ricinus communis* contains malic acid, doubtless combined with potash.

* Ann. de Chim. lxv. 277.

The *phytolacca decandra* contains an uncommon proportion of potash, and an acid which possesses the properties of the oxalic.

The juice of the *vaccinium myrtillus* or *bilberry*, contains a colouring matter, citric, and malic acids, and a considerable quantity of uncrystallizable sugar. Charcoal removes the colouring matter completely from this juice. When diluted with water, and mixed with yeast, it ferments readily, and yields a considerable quantity of sugar.*

8. The liquid found in the nectarium of different flowers has been called *nectar* by Buchner. We have an examination of the nectar of the *agave geminiflora* by M. Buchner, junior.† He found its specific gravity 1·09. It had a sweet taste and a putrid smell, which it lost by exposure to the air. He obtained from it

1 A volatile principle having a putrid smell

2 A very small quantity of pollen

3 An uncrystallizable sugar, with a trace of sulphate of lime.

M. Anthon examined the nectar of the *agave lurida*.‡ Its specific gravity was 1·23. Besides sugar, it contained chloride of calcium, and of magnesium, and albumen.

CHAPTER III.

OF THE GASES IN PLANTS.

In many plants the stem is hollow and filled with air. In others, as the onion, the leaves are filled with air. Air is lodged in the pod of the pea, in the leaves of some species of fuci. In short, there is hardly a plant that does not possess some part more or less hollow, and of course filled with air. Now, it is a question of some curiosity to determine what species of gas thus fills up the hollow parts of plants. Is it common air? Or is it a secretion by the plant itself? On the latter supposition it may be hydrogen gas, azotic gas, carbonic acid gas, or any other gas whatever.

A few experiments were made by Dr Priestley on the air in the sea-weed. He found it sometimes the same as common air; in other cases it contained a greater proportion of oxygen, in others a greater proportion of azote. The air within the leaves of onions and in the bladder of senna he found the same as common air. Air pressed from the stalks of the common *flag* contained a greater proportion of azote than common air.§

The air, in two or three plants examined by Dr Darwin was the

* Vogel, Annals of Philosophy, xii. 232.

† Jour. de Pharmacie, xxi. 307. ‡ Ibid. p. 307.

§ Priestley, iii. 279.

same as common air. Hubert found the air from the arundo bambos worse than common air.

M. Bidault de Villiers examined the air in a considerable number of plants. That in the leaves of the onion was the same as common air. The same observation applies to the air in the petals of the *melo peppo* in the capsules of the *colutea arborescens*, the pods of the *pisum sativum*, the capsules and vesicles of the *staphylea pinnata*, and *nigella damascena*, the stems of the *borago officinalis*, *conium maculatum*, *sonchus oleraceus*. In some cases he found the air in the leaves of onions extinguish a candle; it must, of course, have contained a considerable excess of azote.*

From these few observations it seems to follow, that the air contained in plants is common air, frequently unaltered; but sometimes deprived of a portion of its oxygen. In Dr Priestley's experiment it would appear that a redundancy of oxygen was present. But this experiment would require repetition before it could be considered as authenticated.

CHAPTER IV.

OF BARKS.

The bark is the outermost part of vegetables. It covers the whole plant from the extremity of the roots to the extremity of the branches. It is usually of a green colour: if a branch of a tree be cut across, the bark is easily distinguished from the rest of the branch by this colour. If we inspect such a horizontal section with attention, we shall perceive that the bark itself is composed of three distinct bodies, which, with a little care, may be separated from each other. The outermost of these bodies is called the *epidermis*, the middlemost is called the *parenchyma*, and the innermost, or that next the wood, is called the *cortical layers*.

The *epidermis* is a thin transparent membrane, which covers all the outside of the bark. It is pretty tough. When inspected with a microscope, it appears to be composed of a number of slender fibres crossing each other, and forming a kind of net-work. It seems even to consist of different thin retiform membranes, adhering closely together. This, at least, is the case with the epidermis of the birch, which Mr Duhamel separated into six layers. The epidermis, when rubbed off is reproduced. In old trees it cracks and decays, and new epidermes are successively formed. This is the reason that the trunks of many old trees have a rough surface.

Davy was induced by some observations of Mr Coats of Clifton,

* Ann. de Chim. lxxxviii. 89.

to examine the epidermis of the bamboo, the sugar cane, and the *equisetum hyemale*. He found in them a great quantity of silica. When examined before the microscope, the epidermis of these graminivorous plants constitutes a brilliant retiform tissue: which gives it the harsh feel by which it is distinguished. The epidermis of the bamboo was found to contain 17·4 per cent. of silica, and it had the appearance when pulverized of pounded glass. He found also silica in the epidermis of the sugar cane, the common bog reed (*arundo phragmites*), wheat, barley, and oats. He found a still greater proportion of silica in some other of the graminivorous plants.*

The *parenchyma* lies immediately below the epidermis; it is of a deep-green colour, very tender and succulent. When viewed with a microscope, it seems to be composed of fibres which cross each other in every direction, like the fibres which compose a hat. Both in it and the epidermis there are numberless interstices, which have been compared to so many small bladders.

The *cortical layers* form the innermost part of the bark, or that which is next to the wood. They consist of several thin membranes, lying the one above the other; and their number appears to increase with the age of the plant. Each of these layers is composed of longitudinal fibres, which separate and approach each other alternately, so as to form a kind of net-work. The meshes of this net-work correspond in each of the layers; and they become smaller and smaller in every layer as it approaches the wood. These meshes are filled with a green-coloured cellular substance, which has been compared by anatomists to a number of bladders adhering together, and communicating with each other.

Fourcroy supposes that the epidermis is the same in its nature in all trees, and that it possesses constantly the properties of cork; but this opinion is not likely to be verified. The cortical layers seem, at least in many cases, to have a similar fibrous basis; a basis possessing essentially the properties of flax, which is itself merely the cortical layers of *linum usitatissimum*.

Common cork, which constitutes the epidermis of the *quercus suber*, is composed of a cellular tissue, whose cavities contain a variety of foreign substances, which may be separated by rasping down the cork and treating it with various re-agents as is done with wood, in order to free the *lignin* from foreign matter. Ten parts of common cork when treated in this way are reduced to 7. This residue was considered by Chevreul as a peculiar substance, which he distinguished by the name of *suberin*.

The properties of suberin have not yet been accurately determined, owing to the difficulty of obtaining it in a state of purity. Sulphuric acid readily chars it. Nitric acid gives it a yellow colour, corrodes, dissolves, and decomposes it; converting it partly into suberic acid, partly into a substance resembling wax, partly into artificial tannin, and partly into a kind of starchy matter.†

* Nicholson's Quarto Journal, May, 1799.

† Bouillon Lagrange, Ann. de Chim. xxiii. 50.

Suberin is very inflammable, burning with a lively flame, while at the same time it swells considerably, but does not melt. When distilled it yields water, and a colourless oil; then a yellow-coloured oil. These liquids are all acid. If the distillation be continued, a brown oil comes over with a little ammonia, and a fatty crystallized substance, which does not dissolve in caustic potash. During the process combustible gases are disengaged, and there remains a porous charcoal weighing $\frac{1}{4}$th part of the suberin employed.

Chevreul treated given weights of common cork, washed cork, and suberin, with nitric acid, and obtained the following products:—

	Common cork.	Washed cork.	Suberin.
Fibrous white insoluble matter	0·18	0·9	1·0
Resin	14·72	17·5	10·0
Oxalic acid . . .	16·00	10·6	7·6
Suberic acid . . .	14·40	19·6	22·4
	45·3	48·6	41·0

What is wanting to constitute the hundred parts is a yellow bitter substance held in solution by the mother water, together with carbonic acid and water, formed at the expense of the constituents of cork.

Chevreul obtained from the epidermis of the birch, cherry-tree, and plum, a quantity of suberic acid, which was always the greater the purer the epidermes employed were. Hence it would appear that these epidermes have a constitution analogous to that of cork. According to John, the young epidermis of the birch differs essentially from cork in this respect. It is soluble by boiling in caustic potash ley, and when the brown-coloured solution is treated with an acid, yellow flocks fall, which become brown on drying. This precipitate is slightly soluble in boiling alcohol, but most of it falls again when the solution cools.

The matter of the parenchyma, and the juices which exist in barks, vary extremely, and probably occasion most of the differences between them. Some, as oak bark, are characterized by their astringency, and contain tannin; others, as cinnamon, are aromatic, and contain an essential oil; others are bitter, as Jesuits' bark; some are chiefly mucilaginous, others resinous, &c. But in the present state of the subject, an enumeration of the different kinds of barks is not to be expected. I shall therefore, satisfy myself with detailing the properties of those barks that have been subjected to examination. The following are the most remarkable of these:—

1. *Cinchona. Peruvian Bark.* The tree which yields this celebrated bark is a native of Peru. It was first observed a few miles south of Loxa, a small town on the river Catamayo, nearly in the same meridian with Quito, but in south latitude 4° 1 and at a height of nearly 7000 feet above the level of the sea. The use of this bark in curing intermittent fevers was known to the Americans before the conquest of Peru. But they concealed its virtues from the Spaniards, in consequence of the detestation in which they held

them. It was known, however, to the Corregidor of Loxa in 1638. In that year the lady of Count Cinchon, Viceroy of Peru, was afflicted with an obstinate intermittent fever, which her attendants were unable to cure. The Corregidor of Loxa informed of this, sent a quantity of cinchona to the Viceroy, assuring him, that it would speedily remove the disease of the Countess. In consequence of this information, the Corregidor was himself summoned to Lima, in order to regulate the dose, and point out the method of administering the remedy. Some trials being previously made upon other patients, the Countess took the medicine and was cured. It was this cure that gave the bark celebrity, and made it known in Europe, as a remedy for intermittent fevers. The Countess brought large quantities of it to Lima, where it was known by the name of *powder of the Countess*, and distributed it to all who were afflicted with intermittent fevers. Some months after (probably when Count Cinchon returned to Spain in 1639), she consigned her whole stock of bark to the Jesuits, who continued for some time to distribute it gratis. Hence it came to be known under the name of *Jesuits' bark*. The Jesuits afterwards sent a cargo of it to Cardinal de Lugo at Rome, who distributed it with the same success as the Jesuits had done at Lima, and afterwards consigned it to the Apothecaries' Company at Rome. Hence it came to be known in Italy by the name of Powder of the Cardinal. It was about this time that Louis XIV., while Dauphin, was cured of an intermittent fever by the use of this bark. As he became King in 1643, it is obvious that the cure must have been effected before that period.

In 1640, when Count Cinchon had returned to Spain, his physician Dr Juan de Vega, who had brought a cargo of it from Peru, sold it publicly in Spain at the rate of 100 reals the pound. The sale continued at this price till most of the Cinchona trees in the neighbourhood of Loxa being exhausted, those whose business it was to collect the bark, began to adulterate it by mixing the barks of many other trees. This speedily brought it into such discredit, that the price sank to 8 reals the pound.*

Cinchona, the botanical name of the genus was derived from the lady of count Cinchon, who first gave the bark celebrity. The term *quina* or *quinaguina* applied to the bark is said to have been the Peruvian name given it by the natives of the country.

Peruvian bark was at first brought entirely from Peru. But about the year 1760, Mutis, a Spanish botanist, who went to Santa Fé de Bogota, as physician to the Viceroy Don Pedro Misia de la Cerda, discovered the Cinchona in that country. Since that period a great deal of the bark has been shipped to Europe from Carthagena de Indias.

Humboldt informs us that the quantity of cinchona bark annually exported from America, is between 12,000 and 14,000 hundred weight. Sancta Fé furnishes 2000 of these. 110 are furnished by

* Condamine. Mem. de l'Acad. Royal des Sciences, 1738, p. 226.

Loxa. The provinces of Huamanga, Cuença and Jean de Bracamoros, with the thick forests of Guacabamba, and Ayavaca furnish the rest, which is shipped from Lima, Payta and other parts on the South sea.

Three different kinds of cinchona bark were early distinguished in commerce, namely, the *pale*, the *yellow*, and the *red*. They are derived from three different species of cinchona, which were first accurately described by Mutis.

1. The *pale bark*, which is the kind originally brought from Loxa, is the bark of the *cinchona lancifolia*. This tree is found chiefly in the neighbourhood of the village Ayavaca, at a height of about 7000 feet above the level of the sea, where the mean temperature is about 60°. It is a lofty and handsome evergreen tree, from thirty to forty feet high, and standing usually single; whereas the other species of cinchona are found in groups. The pale bark is now, comparatively speaking, rare. In 1779, the quantity brought to Europe was 4000 quintals, but it is now reduced to 110, according to Humboldt. It is preferred in South America to all other species. It is known to the English by the name of *crown bark*. Two other varieties, probably from distinct species, are known in commerce by the names of *Lagartijada* (*Lizard-like*) and *negrilla* (*blackish*), from the colour of their epidermes. The branches are barked in dry seasons, from September to November, and the bark is carefully dried in the sun. The trees frequently die after this operation.

The bark arrives in Europe packed in chests made of slips of wood, roughly fastened together, and covered with skins. Each chest contains about 200 lbs., well packed, but generally mixed with dust and other foreign matter. The pieces are about 9 inches in length, some of them scarcely $\frac{1}{10}$th of an inch in thickness, singly or doubly quilled, the quills being in size from a swan's quill to an inch and a half. Some pieces have a coarser texture, are thicker and nearly flat. It has a chopped, greyish-coloured epidermis, often much covered with lichens.* The colour is pale fawn, and when moistened, pale orange.

Good pale bark has scarcely any smell when in substance; but when boiled with water, it emits a slightly aromatic odour. The taste is bitter, but not unpleasant, slightly acidulous and austere, having some resemblance to that of the dried petals of the rose. It is light, and breaks with a close fracture, with the internal fibres somewhat drawn out. If it separates into fibres when chewed, it is considered of inferior quality. The powder of the quilled kind is paler than the bark, being of an uniform pale cinnamon colour; but the flat pieces yield a deeper-coloured and browner powder.

Many experiments were made to determine the constituents of this species of bark, especially by Vauquelin;† but it was Pelletier and Caventou who discovered the peculiar principle to which it

* These are species of *Lecanoræ*, *Parmeliæ*, *Strictæ*, and *Collemata*. The presence of the last genus of lichen indicates the bark to be bad.

† Ann. de Chim. lix. 113.

owes its febrifuge properties, These chemists made their experiments upon what they called the bark of *cinchona nitida*, and *cinchona condaminea ;* but from the description of the bark, there is reason to suspect, that the tree which yielded it was nearly allied to the *cinchona lancifolia.**

They obtained a green-coloured fatty matter, a yellow colouring matter, soluble in water and alcohol, and slightly so in ether, tannin, a red extractive matter, kinate of cinchonina, and kinate of quinina, kinate of lime, gum, starch, and lignin. In this country cinchonina is not employed in medicine ; but if it be true that it constitutes the principal alkali in the cinchona bark of Loxa, there can hardly be a doubt that its febrifuge properties must be considerable.

2. The *red bark* was introduced into commerce by Don Sebastian Joseph Lopez Ruiz, in 1778. It is considered as the bark of the *cinchona oblongifolia* of Mutis. The tree which yields it is found in the Andes, growing abundantly along the banks of the mountain streams at Riobamba, Chinchao, Cuchero, and Chacahnassi. It rises to a considerable height, and is covered with smooth brownish bark.

The bark is brought to this country in chests, containing from 100 to 160 lbs. each. It consists of various-sized pieces, covered with a thin, rough, reddish-brown epidermis. Most of the pieces are flat, though some are partially quilled. Under the epidermis there is an intermediate layer, which is dark-coloured, compact, brittle, and seemingly resinous. The internal part is woody, fibrous, and of a rust-red colour. The powder is of a deeper colour than even the internal part of the bark.

It has a weak, but peculiar smell, and its taste is much less bitter; but more austere and nauseous than that of the pale bark. It possesses decided astringent properties, and seems, therefore, to contain more tannin than either the pale or yellow bark. Its constituents, according to the analysis of Pelletier and Caventou, are the same as those of the pale bark. Like it, the proportion of cinchona which it contains, exceeds considerably that of the quinina.

3. The *yellow bark* is the most employed, and most highy esteemed in this country. It is the bark of the *cinchona cordifolia*† of Mutis, a tree which grows in the mountains of Loxa, in the kingdom of Quito, and in those of Santa Fé, at about 7000 feet above the level of the sea. It is a spreading tree, covered with a smooth bark, externally of a brownish-grey colour. This bark is brought to this country in chests, containing from 90 to 100 lbs. each, and consists of pieces about ten inches long, some of them quilled, but the greater number flat. The quilled pieces are less rolled, and thicker than the quilled pale bark; and the epidermis, which is of a

* Ann. de Chim. et de Phys. xv. 289.

† The bark from which quinina is extracted in France, is called by the French, *quinquina calisaya.* But the species of cinchona, to which it belongs, does not seem yet accurately known.

greyish-brown colour, and covered with flat stringy lichens, is more rough and chopped, easily separating, and often as thick as the bark itself, which is about $\frac{1}{8}$th of an inch. The inner bark has a yellow colour, passing into orange. The flat pieces are generally without epidermis, and considerably thicker than the quilled. Both are mixed in the same chest.

Yellow bark, when boiled in water, has nearly the same smell as the pale. The taste is more bitter, but less austere, and no astringency is perceived when a piece of it is chewed. The internal portion has an orange-yellow colour, becoming, when moistened, of a lively orange. The fracture is woody and fibrous, presenting, when examined by a lens, the appearance of parallel fibres, with a yellow-coloured powder in the interstices. It is easily reduced to powder, and the colour of the powder is brighter than that of the bark.

We are indebted to Pelletier and Caventou for the first accurate ideas respecting the constituents of this bark. It contains a yellow-coloured fatty matter, having the smell of the bark; a yellow colouring matter; tannin; extractive; kinates of quinina and cinchonina, but a considerable preponderance of the former; kinate of lime; starch; and lignin.*

A specimen of cinchona bark was lately sent, by the republic of Columbia, to Pope Gregory XVI., under the name of *quinquina pitaya*. It sells in America at a very high price, and is preferred as a much more efficacious cure of intermittents than the common bark. This bark was chemically examined by MM. Folchi and Peretti. The tree which yields it is not known. M. Peretti conjectures that it may be a species of *buena*; Guibourt, that it is the *exostema floribunda*. This bark contains neither cinchonina nor quinina; but a new alkaline principle, to which Peretti has given the name of *Pitaina*. He obtained also

1 Two colouring matters united to gallic acid
2 Gallate of lime
3 Gum
4 Resin
5 Lignin.

Pitaina, when solid and pure, has scarcely a bitter taste. But its salts, when dissolved in water, alcohol, or ether, have a very bitter taste. It melts when heated a little above 212°, giving out bitter vapours, which condense into minute prisms. Then empyreumatic vapours are disengaged. Hot concentrated nitric acid decomposes it. It combines with sulphuric acid, forming a salt composed of

Pitaina	96
Sulphuric acid	4
	100

This salt is white, and crystallizes in small prisms, diverging like

* Ann. de Chim. et de Phys. xv. 345.

a fan. The acetate of pitaina has a bitter taste, and does not crystallize.*

Besides the three species of cinchona mentioned above, it is now well known to botanists, that various others exist. Some of these have been described by Mr Lambert, in his *Illustrations of the Genus Cinchona*, and others by Humboldt. But it is well known that others exist in collections, which have not yet been noticed by botanists. Such is the demand for cinchona bark, that the collectors of it in South America have been often induced to adulterate it, by mixing with it the barks of several other trees, which happen to bear a certain resemblance to that of the true cinchona. Hence it is requisite that the importers and purchasers of cinchona should have the means of examining and determining the goodness of the bark before they buy it. A very simple method of making such an examination was suggested long ago by Vauquelin, and ought to be generally known.†

The chest of bark is in the first place opened, and the pieces carefully compared with each other. It will not be difficult to judge from their appearance whether they are derived from the same species of tree. Should such differences appear, it will be necessary to examine each kind separately, in order to ascertain which of them, or whether any of them be the true bark of cinchona. For this purpose, we may proceed in the following way :—

Reduce 1 ounce of the bark to a coarse powder, and infuse it in a pound of boiling water. Let the infusion cool, and then filter it through paper, and divide the liquid into four equal portions, putting them into four different test glasses. Into the first pour a little of the infusion of nutgalls. If the bark be genuine, there will fall an abundant *white* or *greyish-white* precipitate. This precipitate indicates the presence of *quinina* or *cinchonina*. If the infusion of the bark is not precipitated by infusion of nutgalls, we may at once pronounce that it is not the bark of a cinchona.

Into the second test glass let fall a solution of *persulphate of iron*. The infusion will assume a green colour. Sometimes a copious greenish-black precipitate falls, and the supernatant liquid, when it becomes clear, has a green colour. This is owing to a variety of *tannin*, which the cinchona contains. The more abundant the precipitate, and the more intense the green colour, the better in general is the quality of bark under examination.

Into the third test glass let fall a little solution of isinglass in water. A white or greyish-white coagulum falls. This is owing to the tannin which all good cinchona contains.

Into the fourth test glass drop a solution of tartar emetic. If the bark be of a good quality, a greyish-yellow precipitate will fall. This precipitate is also occasioned by the tannin which good cinchona bark contains.

2. *China nova* is the bark of a tree still little known, but distinguished by the names of *China nova* and *China regia*, which has been

* Jour. de Pharmacie, xxi. 513. † Ann. de Chim. lix. 113.

analyzed by Pelletier and Caventou.* They obtained from it a fatty matter; a red resinous-looking substance, consisting chiefly in extractive from altered tannin. This substance dissolves less easily in potash and concentrated acetic acid, than the red matter from cinchona bark. When dissolved in boiling water it is precipitated by a solution of gelatin, but not by tartar emetic. This bark contains also tannin, which is precipitated by solution of gelatine, but not by tartar emetic, and which, when mixed with persulphate of iron, gives a brown precipitate. The bark contains also a yellow colouring matter, gum, starch, lignin, kinovic acid, and a vegetable alkali extracted by Gruner, but not examined. He informs us that 100 parts of it saturate 12·3 of sulphuric acid. This would make its atomic weight 40·63. Or supposing the salt to be a disulphate the atomic weight of the alkali would be 20·31; which is sensibly the same with that of quinina. Probably, therefore, the alkali in *China nova* is *quinina*; or, perhaps Gruner's alkali may be the substance found more lately in this bark by M. Winkler, and called by him *Chinova bitter*.†

The *kinovic* acid of Pelletier and Caventou has considerable analogy with the oily acids, particularly with *stearic* acid, but it may be obtained without saponification, which is a necessary preliminary for the oily acids. It may be obtained by treating the alcoholic extract of the bark with alcohol and magnesia. The magnesia forms an insoluble compound with the colouring matter, the tannin, and the extractive: while the kinovate of magnesia is dissolved by the alcohol. If we filter the solution, and add an acid, the kinovic acid is thrown down in white flocks. When this acid is dried, it constitutes a brilliant white light matter. It is very little soluble in water, but dissolves readily in alcohol and ether. Water throws it down from its alcoholic solution in flocks. With the bases it forms salts, which are very easily decomposed by the other acids.

The alkaline kinovates are very soluble. The kinovates of barytes and lime are rather more soluble in water than kinovic acid, and dissolve readily in alcohol and ether. Kinovate of magnesia is soluble in water, alcohol, and ether. The solution of it does not precipitate the neutral salts of silver, lead, copper, and protoxide of iron. But it slightly affects acetate of lead and corrosive sublimate. It precipitates the salts of cinchonina.

3. Bark of *Daphne Mezerium*. This bark was examined in 1822 by MM. C. G. Gmelin and Baer.‡ It has been long known, that when applied to the skin, it has the property of raising a blister.

Gmelin and Baer obtained from it wax, an acrid resin, a peculiar crystallizable body, to which they gave the name of *daphnin*, and which has been already described in a preceding Chapter of this volume; a yellow colouring matter, an uncrystallizable sugar, gum,

* Jour. de Pharmacie, vii. 109. † Ann. der Pharm. xvii. 161.
‡ Schweigger's Journal, für Chemie und Physik, xxxv. 1.

reddish-brown extractive, free malic acid, malates of potash, lime, and magnesia, probably malates of iron and alumina, phosphate of lime, traces of phosphate of potash, lignin, and silica.

If we boil the bark of mezereon in alcohol, and filter, while hot, the decoction, on cooling, deposits wax. When we distil the alcoholic decoction, no volatile matter passes over with the alcohol, but there remains an extract which water decomposes into an insoluble resin, and a clear yellow solution. It is to this resin that the bark is indebted for its vesicating property. It has a green colour; so deep, that it appears to the eye black. It is hard, and breaks with a conchoidal fracture. Its taste is extremely acrid. Some time elapses before it is perceived; but it remains very long in the mouth. When isolated, it is only slightly soluble in water, but is much more soluble when mixed with the other principles of the bark. It dissolves in alcohol, and the solution has a deep-green colour. The solution in ether is light green. When distilled *per se*, it gives out no ammonia. When boiled with muriatic acid, it gives out a very disagreeable narcotic smell. A small portion of the resin is decomposed and dissolved, but the greatest part remains unaltered. Nitric acid converts it into oxalic acid, and a light-yellow resinous-looking substance. This last substance, by prolonging the action of the acid, is converted into the bitter substance of Welter, and into artificial tannin.

This resinous body is, in fact, a compound of a fat, acrid, vesicating oil, and another substance. If we dissolve it in alcohol, and mix the liquid with an alcoholic solution of acetate of lead, a green precipitate falls. If we now filter the liquid, and throw down the excess of lead by sulphuretted hydrogen, filter and evaporate the liquid, the oil separates in viscid drops, having a golden-yellow colour. The oil thus obtained has an acrid taste, and vesicates the skin. It is easily converted into soap, and without giving out any disagreeable odour. But if we distil the soap, after having mixed it with tartaric acid, a strong smell of phosphuretted hydrogen is perceived, and a liquid passes over into the receiver, whose smell and taste has considerable analogy to that of weak cinnamon water. This liquid contains a small quantity of acetic acid. There remains in the retort, together with tartrate of potash, oily acids, quite free from all acridity. This oil or resinous-like body contains phosphorus; for when we burn either of them with nitre, we find phosphoric acid in the residue after the combustion. Thus the acrid oil from the bark of *Daphne Mezerion* contains an additional constituent; namely, phosphorus; just as the vesicating volatile oils contain sulphur.

The portion precipitated by acetate of lead gives, if we mix it with alcohol, and free it from oxide of lead by sulphuretted hydrogen, a solution which, after being filtered, is brown, and which, when evaporated, leaves a brown residue. Absolute alcohol separates the colouring matter, and leaves a white unctuous substance, which was not examined. The alcoholic solution is acid, and has

a disagreeable smell, which becomes alliacious, and most disgusting when an alkali is added to the liquid.

Let us now return to the aqueous solution from which the resinous-looking matter had separated. If we distil it in a retort, we obtain a liquid having a disagreeable smell, and a slightly acrid taste. This liquid is rendered slightly muddy by acetate and subacetate of lead; but has no action on vegetable blues. The concentrated liquid is precipitated sulphur-yellow by subacetate of lead. When we filter the liquid, and free it by sulphuretted hydrogen from the oxide of lead which it contains, it leaves, when evaporated, an extract, from which absolute alcohol dissolves *daphnin*, leaving a peculiar brown-coloured extractive matter.

The sulphur-yellow precipitate, thrown down by subacetate of lead, gives, when decomposed by sulphuretted hydrogen, two substances, one of which dissolves while the other remains mixed with the sulphuret of lead. When the solution, containing the first of these, is evaporated, it leaves a sweet-tasted uncrystallizable extractive matter, capable of undergoing the vinous fermentation, and, therefore, a species of sugar. When treated with nitric acid, it gives a great deal of oxalic acid. The second substance may be separated from the sulphuret of lead by boiling water, which dissolves it, but lets it fall, on cooling, in yellow flocks. It has an astringent taste, is soluble in alcohol, and precipitated yellow by acetate of lead, and reddish-grey by persulphate of iron. It has some resemblance to a compound of tannin and starch.

If Mezerion bark, after having been exhausted by alcohol be digested in cold water, we obtain a brownish-yellow gum, which when treated with oxalic acid, yields mucic and oxalic acids. The solution of this gum is abundantly precipitated by the infusion of nutgalls; though the precipitate does not take place immediately. It is also precipitated by acetate and subacetate of lead. When distilled it gives off ammonia. Boiling water extracts from the bark a greater quantity of this gum than cold water does.

Such is an abstract of the curious experiments of Gmelin and Baer, on the bark of Mezerion. Gmelin ascertained that the daphne alpina contains daphnin as well as the daphne mezerion.

4. Bark of the root of the *ailanthus glandulosa* or Japan varnish. This bark was examined by M. Payen,* in 1824. By the successive action of water, alcohol, ether, &c., he separated the following constituents:—*Lignin*, *water*, *starch*, *gum*, *vegetable jelly*, a *bitter substance* soluble in water and alcohol, *aromatic resin*, *chlorophylle*, an *aromatic substance* soluble in water, alcohol, and ether and having a distinct smell of vanilla, a *fatty matter*, a *substance* containing *azote*, soluble in water and insoluble in alcohol, a substance similar to *fungin*, but without azote, a *yellow colouring matter*, traces of a *volatile oil* having a strong and acrid smell, traces of *citric acid*, *silica*, and some *salts*.

* Ann. de Chim. et de Phys. xxvi. 329.

The *aromatic substance* more soluble in alcohol than in water or ether, is remarkable for the striking similarity between its smell and that of vanilla. It is not easy to free it completely from the other constituents of the bark.

The *aromatic resin* gives out an agreeable smell, when it is thrown on a hot iron and evaporates in a white smoke.

The *vegetable jelly* is insoluble in water and alcohol; but forms with ammonia a compound soluble in water. When this compound is dried, it has the form of transparent white plates, which are brittle and not altered by exposure to the air. It is neutral and gives out ammonia when treated with the requisite reagents. When this compound is dissolved in water, the jelly may be separated unaltered, by saturating the ammonia with sulphuric acid. A slight excess of the acid renders the jelly a little soluble in water; but the addition of carbonate of lime restores its insolubility. It is easily re-dissolved by ammonia.

The *substance* analogous to *fungin* possesses all the characters of that substance, but is destitute of azote, which Braconnot showed to be a constituent of the fungin from mushrooms.

5. *Bark of the croton eleutheria.* This bark constitutes the eleutheria and cascarilla of the shops. It is usually in rolled pieces, and has some resemblance to Peruvian bark. It has an aromatic smell, and an agreeable bitter taste. When burnt it emits an aromatic odour resembling that of musk. For the only chemical analysis of this bark hitherto published we are indebted to Professor Trommsdorf; 4696 parts of it yielded him the following products:—*

Mucilage and bitter principle .	864 parts
Resin	688
Volatile oil	72
Water	48
Woody fibres	3024
	4696

6. *Bark of the white willow* (*salix alba*).—The bark of this tree which is common enough in Scotland, is remarkable for its astringent taste, and has been often used in intermittents by the common people. It has lately been proposed by Bouillon La Grange as an excellent substitute for Peruvian bark; being composed, according to him, of the very same constituents, to which that bark owes its medicinal virtues. A very superficial examination, however, may satisfy any one, that the properties of the two are very far from similar.

The decoction of this bark has a dark-reddish colour; and according to Bouillon La Grange, when repeated decoctions are made with the same portion of bark, the last is always deepest coloured. It is precipitated abundantly by glue, carbonate of potash, and car-

* Ann. de Chim. xxii. 219.

bonate of ammonia. Lime-water throws down a precipitate, at first blue, and afterwards buff-coloured. Sulphate of iron throws down a very dark-green precipitate. Alcohol separates white flakes. When evaporated to dryness, a reddish brittle substance remains, which has a very bitter taste, and does not attract moisture from the atmosphere.

When alcohol is digested over this bark, it acquires a greenish-yellow colour. The tincture is rendered muddy by water. When evaporated it leaves a brilliant yellow substance of a very bitter taste which melts at a moderate heat, and emits an aromatic odour.*

These experiments indicate the presence of tannin, bitter principle, extractive, and gluten, in this bark.

7. *Bark of the pinus sylvestris.* This bark having been recommended by M. Westring as a febrifuge, Berzelius was induced to subject it to analysis.† He obtained the following constituents :—

Soft resin	6·92
Tannin with apotheme . .	6·65
Extractive with sugar and bitter principle	15·00
Kinate of lime . . .	0·53
Vegetable jelly . . .	18·15
Moisture and loss . . .	5·25
	52·50
Insoluble matter . . .	47·5
	100

The soft resin is strictly speaking, a combination of resin and volatile oil. It has an agreeable savour of the fir, which it gradually loses as it becomes hard. It has a greenish-brown colour, and its alcoholic solution is greenish-yellow.

The vegetable jelly possesses all the characters of pectic acid. The woody fibres of the young bark possess all the characters of the amylaceous fibrin of potatoes. They swell out in water, and are converted into a gelatinous mass, which, when dried, assumes the aspect of horn. It would appear, from this, that the pectic acid is mixed in fir bark with starch. To this mixture the bark probably owes its nutritive properties, being occasionally employed in times of scarcity in Scandinavia as a substitute for bread.

8. *Bark of the æsculus hippocastanum* or *horse-chesnut.* The bark of this tree, which forms so fine an ornament in parks and avenues, has lately been proposed in Paris as a remedy in intermittents, and a set of observations on it have been published by Mr Henry.‡ Water or moderately strong spirits are the best solvents of it. Strong alcohol dissolves but little. The watery infusion has a fawn colour and a bitter taste, without astringency. It is precipi-

* Ann. de Chim. liv. 290.

† Afhandlingar, iii. 347, and Traité de Chimie, vi. 228.

‡ Ann. de Chim. lxvii. 205.

tated abundantly by gelatine, and sparingly by acids. It precipitates iron green. With nitrate of mercury it forms a copious precipitate. The infusion of nutgalls and tartar emetic produce no effect upon it. From these properties it is obvious that it differs entirely in its constituents from the different species of cinchonæ examined by Vauquelin.

M. Canzoneri, however, has announced that it contains an alkaloid very similar to quinina or cinchonina. (See *Jour de Pharmacie*, ix. 542.) He has given it the name of *æsculin*.

9. *Bark of quercus robor*, or *oak*. This bark, so long and universally employed for tanning leather, has been but imperfectly examined. Davy found long ago, that 100 parts of it contain 12·7 parts of extractive, and 6·3 of tannin. Braconnot found that it contained a considerable quantity of pectin.* When oak bark, after having been exhausted by tanning, is put into water, a kind of fermentation takes place, and an acid liquid is formed, which is employed in one of the preliminary processes of tanning. Braconnot has shown that the acid thus formed is the lactic; and the liquid, called *jusée*, by French, contains acetate of lime, tannin, apotheme, a gummy matter, free acetic acid, and a great quantity of lactate of lime, together with lactates of magnesia, potash, ammonia, and probably of manganese and iron.†

10. *Bark of Populus tremula.* The bark of this tree has drawn the attention of chemists, in consequence of Braconnot's discovery of two febrifuge principles in it, to which the names of *salicin* and *populin* have been given. These substances have been already described in a preceding Chapter of this volume.

The infusion of this bark, when treated with persulphate of iron, tartar emetic, gelatine, and infusion of nutgalls, exhibits exactly the same characters as the infusion of cinchona bark. Besides salicin and populin, it contains a species of tannin, apparently the same with that in cinchona bark, and which furnishes the same red coloured apotheme. This tannin has the characteristic property of assuming a light-green colour when supersaturated with caustic magnesia, and exposed to the air. This phenomenon does not appear when lime is substituted for magnesia. Nor has it been perceived in any other kind of tannin.

To the apotheme from the tannin of the trembling poplar, Braconnot has given the name of *corticin*, because it is generally met with in barks. Besides the substances already mentioned, Braconnot found in this bark *gum*, a *peculiar substance*, soluble in water and alcohol, and which, when mixed with salts of gold, silver, or mercury, reduces the oxides to the metallic state; *tartrates of potash and of lime, pectic acid and lignin.*

11. *Betula alba.* The epidermis of the *birch* tree is composed of a number of layers, easily separable from each other, and very combustible. It was examined by Gauthier, who extracted from it

* Ann. de Chim. et de Phys. l. 381. † Ibid. p. 376.

Resin	46·5
Extractive	11·25
Suberin	23·00
Gallic acid and tannin	5·5
Alumina	2·0
Oxide of iron	4·5
Silica	3·75
Carbonate of lime	2·5
	99·00*

12. *Bark of the Winterania canella.* This bark was examined in 1819, by M. Henry.† It contains an acrid *volatile oil*, an aromatic *resin*, *coloured extractive*, an *extractive matter* soluble in boiling water, *gum*, *starch*, *vegetable albumen*, *acetates*, *oxalates*, *and chlorides of lime and potash*, *and lignin*. In 1822, Petroz and Robinet‡ examined the same bark, and found, in place of the coloured extractive, and the extractive soluble in boiling water, a peculiar species of sugar, and a very bitter-tasted extractive. But the rest of their analysis agrees with that of Henry. The sugar crystallizes, and seems to be a variety of mannite.

13. Bark of *angustura vera.* M. Saladin has ascertained, that when the infusion of the *angustura vera* is treated cold, with absolute alcohol, and the liquid is left to spontaneous evaporation, crystals are deposited, to which he has given the name of *cusparin*. The crystals are tetrahedrons.

Cusparin is neutral. It melts at a low temperature, losing 23·09 per cent. of its weight. Cold water dissolves half a per cent., and boiling water 1 per cent. of it. It dissolves in the concentrated acids, and in the alkalies. It is precipitated by the infusion of nutgalls.§

14. Bark of *buxus sempervirens*, or box tree. This bark was subjected to a chemical examination by M. Fauré, who found it to contain

1	Chlorophylle	0·6
2	Buff-coloured matter	0·3
3	Wax	1·4
4	Azotized tallow	1·1
5	Resin	4·0
6	Extractive	14·1
7	Malate of buxina	1·1
8	Gum	4·4
9	Lignin	67·8
10	Ashes	5·2
		100·0

The ashes consisted of sulphates of potash and lime, carbonates of lime and magnesia, phosphate of lime, oxide of iron, silica.‖

Buxina has been described in a preceding part of this volume.

* Jour. de Pharm. xiii. 545. † Ibid. v. 480. ‡ Ibid. viii. 197.
§ Ibid. xxii. 662. ‖ Ibid. xvi. 428.

15. *Quillaia saponaria.* When the bark of this tree, which is a native of Chili, is pulverized, and mixed with water, it froths like soap, and is generally employed as a substitute for soap, by the inhabitants of the country. A small portion of the bark of this tree was put into the hands of MM. Henry, jun., and Boutron-Charlard for analysis, by M. L'Eveillé. But the result of the analysis was imperfect, in consequence of the small quantity of bark at the disposal of these chemists. They obtained

1. A peculiar sharp-tasted substance, soluble in water and alcohol, frothing when agitated with water, and drying in thin transparent crusts.
2. A fatty matter, combined with chlorophylle.
3. Sugar.
4. A brown colouring matter, rendered deeper by the alkalies.
5. Gum, a trace.
6. A free acid.
7. Malate of lime.
8. Starch.
9. Chloride of potassium, and phosphate of lime.
10. Oxide of iron.
11. Lignin.*

CHAPTER V.

OF ROOTS.

The roots of a great variety of plants are employed in medicine and the arts. The substances found in them are various; and indeed, as the peculiar juices of the roots are always included in such examinations, it is clear that almost all the vegetable principles will be found in them. I shall notice in this Chapter the principal roots employed in medicine and the arts.

1. *Beta vulgaris.* There are two varieties of the *beet*, one, the roots of which are red, while those of the other are white. The root is large and pulpy, somewhat like that of the carrot; but much larger. It has been long cultivated as a nourishing food for cattle. The root of the beet is sweet, owing to the presence of sugar in it. M. Pelouze has shown that it contains no mannite nor uncrystallizable sugar, but only a sugar exactly the same as that obtained from the sugar cane.†

When the root of white beet is grated down to a fine pulp, and the juice expressed, and the residue thoroughly washed and dried over the water-bath, 100 parts of the root only leave 2·5 parts of the residue. But the manufacturers of beet-root sugar only express 70 per cent. of juice, and leave 30 per cent. of residue. This must be owing to the imperfection of the method employed by them, for

* Jour. de Pharmacie, xiv. 252. † Ann. de Chim. et de Phys. xlvii. 411.

reducing beet-root to a pulp. For when M. Pelouze grated down the pulp, by means of a hand rasp, he never obtained more than 12 per cent. of residue.*

M. Pelouze determined the quantity of sugar in a given weight of beet-root, by mixing its juice with yeast, and converting it into alcohol by fermentation. The specific gravity of the alcoholic liquid obtained, gave him the quantity of alcohol formed from a given weight of beet-root. He had previously ascertained, that 100 parts of sugar furnished exactly 51 parts of anhydrous alcohol. The following table exhibits the results obtained with 27 varieties of beet:

	Sugar per cent.
White beet from Bondue†	5·8
Do.	6·2
Do. (well manured)	6·3
Do.	7·2
Do.	7·2
Do.	7·5
Do. (well manured)	8
Do.	8·0
Do. (well manured)	8·3
Do.	8·5
Do. (well manured)	9·0
Do.	9·2
Red Beet (well manured)	9·8
Do.	9·8
White beet, from Famars‡	7·2
Red, from do.	6·6
White, with red skin, from do.	9·2
Red, from do.	9·8
White, from do.	8·5
Yellow, from do.	9
Red beet, from Famars	9
Beet of two years after seeding	0
Red beet of 1 year	7·5
White do., from Dunkirk	8·2
Do. with red skin, from do.	9·5
White do., from Arras	9·5
Do. with red skin, from do.	10

Beet-root has been examined by M. Payen§ and M. Dubrunfaut, as well as by M. Pelouze. Besides sugar, they found *albumen*, a *substance* containing *azote*, *lignin*, *pectic acid*, *malate of potash*, *oxalate of potash*, *ammonia*, and *lime*.

2. *Anthemis Pyrethrum*, or *pellitory of Spain*. The root of this plant, formerly much used as a gargle, and still employed as a sialagogue, was analyzed by M. Koene, in 1835.‖ It had been previously subjected to a chemical examination by MM. Gautier¶ and Parisel.**

* Jour. de Pharmacie, xvi. 418. † Bondue is a village 2 leagues from Lille.
‡ Near Valenciennes. § Jour. Chim. Med. i. 385.
‖ Ann. de Chim. et de Phys. lix. 327. ¶ Jour. de Pharm. xix. 251. ** Ibid. iv. 49.

The root is long, fusiform, about the thickness of the finger, rough, fawn-coloured externally, white within, fibrous, and almost destitute of smell. Its taste is acrid and slightly acid, and leaves a very lasting impression in the mouth.

There is some difference in the results of the different chemists, in their accounts of the constituents of this root. M. Gautier obtained

Volatile oil, a trace	—
Acrid fixed oil	5
Yellow colouring matter	14
Gum	11
Inulin	33
Chloride of calcium, trace	—
Lignin	35
	98*

He considers the property of the root of pyrethrum to excite a flow of saliva to reside in the fixed oil, which has a brown colour, and is lighter than water.

M. Parisel obtained

Acrid matter (pyrethrin)	3
Inulin	25
Gum	11
Tannin	0·55
Colouring matter	12
Lignin	45
Chloride of potassium	0·79
Silica	0·85
Iron	trace
	98·19

With a trace of volatile oil.

M. Koene, whose analysis was published in 1835, obtained

A brown acrid resin, insoluble in caustic potash	0·95
An acrid brown fixed oil, soluble in caustic potash	1·60
A yellow acrid oil, soluble in potash	0·35
Tannin, a trace	—
Gum	9·40
Inulin	57·70
Sulphate, muriate, and carbonate of potash, phosphate and carbonate of lime, alumina, silica, oxides of iron and manganese	7·60
Lignin	19·80
	97·40†

The active principle of the root from this analysis consists of three different substances. It is soluble in sulphuric and acetic ether, and in alcohol. Water partly separates it from the alcoholic solution, but the liquid remains muddy. It is quite insoluble in water. Muriatic and nitric acid have no sensible action on it.

* Jour. de Pharmacie, iv. 50.

† Ann. de Chim. et de Phys. lix. 328, and Jour. de Pharmacie, xxii. 88.

Concentrated sulphuric acid dissolves it, and destroys the acrid principle. If we add water to the solution, flocks precipitate, and a fœtid odour is developed.

Caustic potash partly dissolves the acrid principle, leaving undissolved a brown acrid matter. The solution mixes in all proportions with water, and the acids separate the oil unaltered.

The insoluble brown matter has an insupportably acrid taste. It is insoluble in weak alcohol. Strong alcohol dissolves it, and the solution becomes milky when mixed with water; so that it possesses the characters of a resin. To the acrid substance M. Parisel has given the name of *pyrethrin*. But it appears from these results of M. Koene, that it is not a simple vegetable principle as he supposed, but a compound of two oils and a resin.

Probably the difference in the proportion of the constituents in the analyses of Gautier and Koene, was owing, at least in part, to differences in the roots examined.

3. *Daucus carota*. The root of this plant, the common *carrot*, is too well known to require any description. It has been subjected to an analysis by M. Vauquelin* and by M. Wackenroder.† Vauquelin showed that the expressed juice of the carrot contains common sugar, incrystallizable sugar and mannite, but none of this last substance could be discovered till the common sugar had been subjected to fermentation, and converted into alcohol. He found in it also a fatty resinous matter, and albumen, malic acid, and a peculiar principle held in solution by the sugar. The residue of the carrot, freed from its juice, when treated with potash, yields, as Braconnot had already shown, abundance of pectic acid. When pectic acid is heated in a crucible, with an excess of potash, (taking care not to raise the heat too high) it is converted into oxalic acid.

Wackenroder informs us that the carrot juice has a brick-red colour, and is muddy. Its smell is similar to that of carrots, its taste sweet, but harsh. It coagulates at a temperature under 212°. The coagulum is yellow, and when dried amounts to 0·629 of the juice. It is composed of 0·435 of vegetable albumen, and 0·10 of a fatty oil, 0·034 of *carotin*, and 0·06 of earthy phosphates. When this juice is distilled, it gives out $\frac{1}{3700}$ of its weight of volatile oil. This oil is colourless, has a strong carroty smell, a strong taste, remaining long in the mouth, and a specific gravity of 0·8863, at the temperature of 54°. It is little soluble in water, but very soluble in alcohol and ether.

The substance to which Wackenroder has given the name of *carotin*, may be extracted by ether, either from coagulated carrot juice, or from carrots cut into thin slices and dried. The ether contains the carotin, mixed with a fatty colourless oil. If we evaporate away the ether, and treat the residue with caustic ammonia, the oil will be saponified and dissolved, while the carotin remains behind. Redissolve it in ether, add a little alcohol to the solution,

* Ann. de Chim. et de Phys. xli. 46.

† Commentatio de Anthelm. de Regn. Veg. Gott. 1826.

and leave it to spontaneous evaporation. The carotin crystallizes in small ruby-red needles, mixed with globules of the oil. Put the crystals on bibulous paper to absorb the oil, and wash the carotin with a little ammonia.

The crystals are very small oblique four-sided tables. Carotin has neither taste nor smell, and has no action on vegetable colours. Heat softens, but does not melt it. It is not volatile, but burns when heated, without leaving any residue. It is slightly soluble in anhydrous alcohol. Ether does not dissolve it, unless when it is mixed with fat oil. It is soluble in fixed and volatile oils, butter, and other analogous substances. The solutions are yellow, and are speedily rendered colourless by exposing them to the solar rays. This is the reason why carrots do not yield carotin, except when they are fresh.

4. *Bryonia alba, white bryony.* The root of this plant, which is so abundant in the middle districts of Europe, was formerly a good deal employed in medicine. The fresh root, when taken into the stomach, acts violently as an emetic and purgative, and was at one time thought to produce temporary madness. This root is large, long, fleshy, compact, externally yellowish-grey, internally white. It is marked by transverse streaks. Its taste is nauseous, very acrid, bitter, and slightly astringent when fresh; but it loses these characters when dried.

It was analyzed by Vauquelin in 1807,* afterwards by MM. Brandes and Firnhaber,† and by Duleng d'Astafort.‡

It has a certain analogy with the root of *beta vulgaris*, but contains much less sugar, and is distinguished by a peculiar bitter-tasted substance, discovered by Vauquelin, which has been distinguished by the name of *bryonite.* According to Brandes and Firnhaber, the root of *bryonia alba* is composed of

Bryonite, with a little sugar	1·9
Resin, with a little wax	2·1
Soft resin	1·3
Mucoso saccharine matter	10·0
Gum	14·9
Starch	2·0
Pectic acid	2·5
Fibrous starch	1·0
Coagulated albumen	6·2
Mucilage	0·27
Extractive	1·7
Phosphates of magnesia and alumina	0·5
Malate of magnesia	1·0
Fibrin	15·25
Water	20·0
	80·62

* Ann. de Mus. d'Hist. Nat. viii. 88. † Br. Arch. iii. 351.
‡ Jour. de Pharmacie, xii. 158, 325, 507.

The properties of the bitter substance called *bryonite*, and the mode of obtaining it, have been detailed in a preceding Chapter of this volume.

5. *Cyclamen Europeum*, or *sow-wort*. The root of this plant, which is a native of Britain, was formerly employed in medicine, under the name of *radix arthanitæ*. This root is fleshy, very thick, approaching to round, and at least as large as the fist. It is black exteriorly, but white within. It has no smell, but an acrid bitter and disagreeable taste. It was at one time employed as a laxative. Saladin found in the root of this plant a peculiar crystalline substance, to which he gave the name of *arthanitite*. We have given an account of this substance in a preceding Chapter of this volume.

6. *Berberis vulgaris*, or *barberry*. The bark and the fruit of this plant were formerly used in medicine. The root was analyzed by Brandes,* and more lately by Buchner and Herberger.† Brandes found the constituents of this root as follows :—

Brown colouring matter, thrown down by acetate of lead	2·55
Yellow colouring matter, not thrown down by acetate of lead	6·62
Gum, with a trace of calcareous salt	0·35
Starch, with a little phosphate of lime, &c.	0·20
Calcareous phosphates	0·20
Fat oil	0·40
Chlorophylle	0·025
Soft resin	0·55
Lignin	55·40
Water	3·50

Buchner and Herberger extracted from the same root the following constituents :—

Wax	0·4
Tallow	0·6
Resin	20·4
Berberite	17·6
Gum	21·4
Starch, traces of	——
Malates and phosphates	3·4
Lignin	31·2
Ashes	2·6
Water and oil	2·0
	99·6

Berberite is an extractive substance containing azote, having a yellow colour and a bitter taste. Its characters and the manner of obtaining it have been given in a previous Chapter of this volume.

* Br. Arch. xi. 29.

† Jour. de Pharmacie, xvii. 39, and xxi. 309.

7. *Rheum palmatum, australe, undulatum*, &c. *Rhubarb.* The roots of various species of rheum constitute the well-known and valuable medicine called *rhubarb.* Our rhubarb is quite different from the *Rheum* or *rhabarbarum*, which Dioscorides informs us was black, and came from beyond the Bosphorus. Our rhubarb* was imported from China and Tartary, by the way of Russia. When it began to be used as a medicine, I do not know, but it was obviously in common use in the time of Paracelsus, who died in 1541, being mentioned by him as a common purgative.† But it was not till the year 1732, that naturalists became acquainted with any plant which seemed to yield the rhubarb of the shops. At that time, Jussieu in Paris, and Rand at Chelsea, received from Russia some plants, which were said to be those that yielded it. From these, Linnæus drew up his description of *rheum rhabarbarum*, which appeared in the first edition of his *Species Plantarum.* Dr. Hope, Professor of Botany in Edinburgh, raised the true rhubarb plant from seeds sent him by Dr. Mounsey from Petersburg, and drew up a botanical description of it, under the name of *rheum palmatum*, which was published in the *Philosophical Transactions* for 1765.

Three varieties of rhubarb are known in commerce, *Russian*, *Turkey*, and *East India*, or *Chinese* rhubarb. The two first grow on the declivities of a chain of mountains stretching from the Chinese town Sini, to the Lake Koko Nar, near Thibet. It is also cultivated in China.

Good rhubarb is in flat, irregular, angular pieces, full of large holes. Its colour is a pure yellow, marbled with red and white veins. It has a peculiar smell, and a bitter, slightly astringent taste. It feels gritty between the teeth; and when chewed tinges the saliva of a bright yellow colour. It breaks with a rough hackly fracture, is easily reduced to a powder, which has a bright buff-yellow colour. It should not be porous, but rather compact and heavy.

Schrader analyzed Russian rhubarb, and the root of rheum palmatum with great care, and obtained from it the following constituents:—

	Russian.	R. Palmatum.
Resin . . .	4·8	2·8
Bitter principle of rhubarb	26·4	24·0
Oxalate of lime .	4·5	9·0
Lignin . . .	49·5	47·0
Gum . . .	12·8	14·8
	98·0	97·6

Brande found in the root of rheum palmatum,

* Mr David Don has shown, that the plant which yields the East Indian or China rhubarb, is the *rheum australe.*

† Paracelsi Opera Omnia, ii. 27. Archidoxorum, lib. 7. Geneva folio edition of 1658.

Resin	10
Bitter principle of rhubarb	26
Gum	31
Lignin	16·3
Malate of lime	6·5
Phosphate of lime	2·0
Water	8·2
	100·0

Hornemann analyzed three varieties, and obtained

	Russian.	English.	Rhaponticum.
Bitter principle	16·042	24·375	10·156
Yellow colouring matter	9·583	9·166	2·187
Extract containing tannin	14·687	16·458	10·416
Apotheme of tannin	1·458	1·249	0·833
Vegetable mucilage	10·000	8·333	3·542
Substance obtained by pot-ash from the woody fibre	28·333	30·416	40·209
Oxalic acid	1·042	0·833	—
Fibrin	13·583	15·416	8·542
Moisture	3·333	3·125	6·043
Rhaponticina	—	—	1·043
Starch	—	—	14·583
	98·061	109·371	117·554*

M. Ossian Henry has analyzed specimens of the roots of rheum australe, which had been cultivated near Paris, and obtained

Rhein	7·3
Fixed oil, a trace	—
Bitter principle of rhubarb, or caphopurite	14·0
Apotheme of tannin	5·0
Extract, with tannin and gallic acid Gum, with binoxalate of lime	1·6
Sugar, a trace	—
Starch	2·0
Oxalate of lime	3·3
Phosphate and sulphate of lime, oxide of iron	0·5
Pectin and pectic acid	46·0
Fibrin	20·3
	100·0†

8. *Imperatoria ostruthium*, now considered by modern botanists as a species of *pastinaca*, and distinguished by the name of *pastinaca ostruthium*, was at one time cultivated in this country as a pot-herb.

* These tables are copied from Berzelius, *Traité de Chimie*, vi. 205. The numbers are obviously inaccurate; but I cannot rectify them, as I have no copy of Hornemann's original paper, from which they were taken by Berzelius.

† Jour. de Pharmacie, xxii. 402.

The root of it was examined by M. Osann, who discovered in it a peculiar principle, which Wackenroder, who examined it particularly, distinguished it by the name of *imperatrin*. This principle may be obtained by the following process:—

Digest the root in ether till every thing soluble in that liquid is taken up. Distil off the greatest part of the ether, and leave the residue to evaporate spontaneously. The imperatrin crystallizes, and a fat oil remains, which is to be decanted off. Subject the crystals to pressure between folds of blotting paper, and then dissolve them in boiling alcohol. When the solution cools, or is allowed to evaporate, the imperatrin crystallizes in oblique four-sided prisms, which are colourless, transparent, and have a vitreous aspect. Taste peppery, and extremely acrid and burning. When pure it has no smell, but it often retains a little volatile oil, from which it may be freed by fusion. It melts when heated to 167°. When exposed to a higher temperature than this, it gives out an acrid smell, and burns without leaving any residue. When distilled it undergoes decomposition, but gives out no ammonia.

It is insoluble in water. 100 parts of alcohol of the specific gravity 0·848 dissolves at the temperature of 59°, 7·11 parts of imperatrin. The solution, which is neutral, is precipitated by water. Ether, oil of turpentine, and olive oil, dissolve it with facility. Caustic ammonia dissolves very little of it; but caustic potash dissolves it abundantly. The acids throw it down from this solution unaltered. Sulphuric acid dissolves imperatrin, assuming, at the same time, a brownish-red colour. Water throws down the imperatrin without colour from this solution. Concentrated nitric acid dissolves the imperatrin without the assistance of heat, giving it a yellow colour. By dilution the imperatrin is thrown down, of a beautiful orange colour. Iodine combines with imperatrin, forming a compound of a brownish-red colour, from which the iodine may be almost completely driven off by heat.*

9. *Polygala senega*. The root of this plant the *senega* of pharmacy, which is a native of Virginia, and distinguished by the name of *rattlesnake root* was employed by the native Americans as a cure for the bite of the rattlesnake. This circumstance was made known to the medical world in 1735, by Dr John Tennant,† who had tried its virtues, and found them to hold good. Symptoms of pleuritic affections generally following the bite of the rattlesnake, Dr Tennant was naturally led to try the exhibition of the root in these diseases, and he assures us that it was of considerable value. In 1739 it was tried by Du Hamel, who found it a powerful expectorant.‡ In 1744, it was exhibited by M. Bouvard in dropsy, and according to his testimony, it is a very powerful hydrogogue.§

The root is woody, branched, contorted, about the thickness of

* Berzelius, Traité de Chimie, vi. 195.

† See his Physical Disquisitions, p. 2.

‡ Mem. Paris, 1739, p. 135. § Ibid. 1744, p. 37.

the finger, and covered with ash-coloured bark. It has no smell. Its taste is at first sweetish and nauseous, but when chewed for less than a minute it becomes pungent, producing a peculiar and disagreeable sensation in the fauces.

This root was analyzed in 1804 by Gehlen,* who obtained the following constituents:—

Soft resin	7·5
Senegin	6·15
Extractive, sweet and acrid .	26·85
Gum with albumen . .	9·50
Lignin	46·00
	96·00

The characteristic properties of the root are ascribed to the *senegin*, which may be obtained by the following process:—

Reduce the root to small fragments, and digest it in alcohol till every thing soluble in that liquid is taken up. Distil off the alcohol from this solution till only $\frac{1}{6}$th of the liquid remains in the retort. During the distillation an oleaginous matter rises to the surface of the liquid. Evaporate this residue to dryness, reduce what remains to powder and digest it in ether till every thing soluble is taken up. When we distil off this ether a soft resin remains. This resin is brownish-red, unctuous, very fusible, has a smell similar to that of the root, a bitter and slightly acrid taste. Alcohol, ether, oil of turpentine, and olive oil dissolve it with facility. The alcoholic solution reddens litmus paper. Nitric acid scarcely attacks it. Caustic soda dissolves it assuming a reddish-brown colour.

The portion insoluble in ether is treated with water, which dissolves an extractive matter at once sweetish and acrid. What remains is *senegin*. It ought to be well washed with water.

It is a greyish-white, swollen matter, something like mucilage of starch. When dried it is translucent, brown, hard, and brittle. Its taste is acrid and irritating, similar to that of the root itself. Weak alcohol dissolves more senegin than strong alcohol. The solution reddens litmus paper. Boiling anhydrous alcohol saturated with senegin deposits it in part on cooling. Senegin is insoluble in ether, and in fat and volatile oils. Though pure senegin be insoluble in water, it becomes soluble in that liquid when it is mixed with the other constituents of the root.

Senegin, when heated, does not melt, but swells up, gives out fumes, and burns with the smell of burning tartar, leaving a porous charcoal. Caustic soda dissolves it into a brown transparent liquid. Nitric acid dissolves it when assisted by heat, and when the solution is concentrated to a certain point, it assumes the form of a jelly.

Senega was afterwards analyzed by Feneulle, Dulong,† and Folchi‡. But the latest and most elaborate analysis was made by M. Quevenne in 1836.§ He obtained

* Berlin Jahrbuch, 1804, p. 112.

† Jour. de Pharmacie, xiii. 567. ‡ Ibid. p. 617. § Ibid. xxii. 449.

1 Polygalic acid, the senegin of Gehlen
2 Virgineic acid
3 Pectic acid
4 Tannin
5 Yellow bitter colouring matter
6 Gum
7 Albumen
8 Cerin
9 Fixed oil.

The characters of *polygalic* acid have been given in a preceding part of this volume. The virgineic acid was obtained only in the fixed oil which exists in the senega root in considerable quantity. It has a reddish-brown colour, a syrupy consistence, a bitter rancid very disagreeable taste, and a smell similar to its taste. It reddens litmus paper. When boiled with water and filtered, the aqueous liquid has a sweet taste, which becomes gradually somewhat bitter and nauseous. Persulphate of iron gives it a red colour, but occasions no precipitate. Diacetate of lead gives a copious yellow precipitate. Nitrates of silver and barytes occasion no change. Acetate of copper gives a greyish-green scanty precipitate. Potash communicates a reddish-tint.

Another portion of this oil was treated hot with a solution of caustic potash. It was easily converted into a soap. After a few minutes boiling, the soap readily dissolved in water. It was decomposed by tartaric acid, the tartrate of potash was separated. It was distilled, a liquid having a disagreeable smell was obtained, on which floated a few drops of oil. The aqueous liquid reddened litmus, precipitated diacetate of lead white, but had no action on salts of silver and copper.

From these, and some other properties, Quevenne considers this oil as consisting chiefly of a peculiar fatty acid, to which he proposes to give the name of *virgineic acid*. But the results obtained are not quite satisfactory.

10. *Helleborus hyemalis*. The root of this plant is tuberous, has a yellowish-white colour, and is covered with a black skin. At first it has no taste: but in a short time a strong acridity becomes sensible in the mouth and throat. Vauquelin has subjected it to a chemical examination, chiefly in order to ascertain the nature of the bitter and acrid principle which it contains. This principle he found to be an oil of a peculiar nature, possessing properties intermediate between the fixed and volatile oils. He obtained it by digesting the root in alcohol, and then distilling off the alcohol in an alembic. The oil gradually separated and concreted on cooling. Its taste was extremely acrid, and it had a yellowish-brown colour. When dissolved in weak alcohol, it precipitates the sulphates of iron of a fine purplish-red colour, which becomes green by means of alkalies. This oil is extremely poisonous, and, according to Vauquelin, exists in many plants, and is the cause of their poisonous qualities.

When the root is digested in water, and the liquid passed through a cloth, it is obtained opaque and milky, and gradually deposits a white powder which possesses the properties of starch. The liquid, by evaporation, deposits a brownish matter, which forms successive pellicles on the surface. This substance possesses the properties of extractive. Besides these substances, Vauquelin detected a substance analogous to gluten, some sugar, and a portion of woody fibre.*

11. *Ipecacuan.* This is the root of a plant which grows spontaneously in Brazil, and probably in other parts of South America. It was first correctly described and figured by Dr Brotero, under the name of *callicocca ipecacuanha.*† But more recently the genus *callicocca* has been united to that of *cephaelis.* The root is about the thickness of a quill, unequal and knotty, and varies considerably in its colour. When pounded it forms the mildest and safest emetic in the whole Materia Medica. Though probably employed in America from time immemorial, it was not introduced into Europe till the time of Lewis XIV., when one Grenier, a French merchant, brought 150 lbs. of it from Spain; with which trials were made at the Hôtel Dieu. Helvetius first made known its use in dysentery, for which he was rewarded by Lewis XIV. with L.1000 sterling.‡

This substance has been analyzed by MM. Majendie and Pelletier. The following are the constituents which they obtained :—

Oil	2
Emetina	16
Wax	6
Gum	10
Starch	42
Wood	20
Loss	4
	100§

12. *Asclepias vincetoxicum.* This plant, the *cynanchum vincetoxicum* of Mr Brown, is a native of the south of Germany. Its roots are employed in medicine in some parts of the continent, though they do not enter into the Materia Medica of Great Britain. They consist of contorted febrillæ, issuing from a common head. They are long, slender, and have a pale yellow colour, a strong smell which mostly disappears when they are dried, and a bitter acrid disagreeable taste. As these roots, like epicacuanha, excite vomiting, M. Feneulle was induced to subject them to a chemical analysis, to ascertain whether they contained *emetina.*‖ He obtained the following substances :—

1 An emetic matter different from emetina; *asclepin.*
2 Resin
3 Mucilage
4 Starch

* Ann. de Mus. Nat. No. xliii. 82. † Linnæan Trans. vi. 137.
‡ Neumann's Chem. p. 357. § Ann. de Chim. et de Phys. iv. 180.
‖ Jour. de Pharmacie, xi. 305.

5 A fixed oil, almost of the consistence of wax
6 Volatile oil
7 Pectic acid
8 Lignin
9 Malates of potash and lime
10 Silica, oxalate of lime, with sulphate, phosphate and carbonate of lime.

The asclepin was obtained in the following manner:—A decoction of the roots was mixed with acetate of lead, which threw down the malic acid and malate of lime. The filtered liquid was then freed from lead by sulphuretted hydrogen gas, and evaporated to the consistence of an extract. Alcohol being digested on this extract, left a quantity of gummy matter, and dissolved a resin together with the asclepin. The alcoholic solution was evaporated and the residue treated with water. The asclepin was dissolved and the resin left behind. The asclepin was freed from all traces of resin by repeated solutions in water.

Thus purified it has a pale yellow colour, attracts moisture from the air, and is very soluble in water, alcohol, and ether containing alcohol. It contains no azote, and does not exhibit any alkaline properties. Its aqueous solution does not precipitate acetate of lead; but corrosive sublimate, infusion of nutgalls and diacetate of lead occasion a precipitate. Infusion of nutgalls does not throw it down immediately. Nitric acid converts it into oxalic acid. Sulphuric acid chars it. When given to the extent of 3 grains it operates as an emetic.

13. *Jalap.* This very active cathartic is the root of the plant formerly called *convolvulus jalappa;* but which Dr Redmond Coxe, of Philadelphia, has shown to be a species of *Ipomæa.* He calls it *Ipomæa jalappa.* It is a native of Mexico, and is said to have taken its name from Xalapa, a province of New Spain, where probably it was first employed in medicine. But the best Jalap comes from Vera Cruz, in South America. According to Bauhin, it was first brought to Europe in 1609, or 1610.

In the shops we find the root both cut into slices and entire. It has an olive shape, is solid, ponderous, blackish on the outside, but grey within, and marked with several dark veins. It has scarcely any smell. Its taste is not strong, but to the tongue and throat it manifests a slight degree of pungency.

It was analyzed by Mr Henry, who found its constituents resin, extractive, starch, and lignin.* According to him, the proportions of these different substances, contained in 500 parts of the three varieties of jalap which occur in commerce, are the following:—

	Resin.	Extract.	Starch.	Lignin.
Jalap leger .	60	75	95	270
—— sain .	48	140	102	210
—— piqué .	72	125	103	200

* Ann. de Chim. lxxii. 275.

It was analyzed in 1817, with much care by M. Cadet de Gassicourt, who made it the subject of his thesis.* He obtained

Water	4·8
Resin	10·0
Gummy extract	44·0
Starch	2·5
Albumen	2·5
Lignin	29·0
Phosphate of lime	0·8
Chloride of potassium	1·6
Chloride of calcium	0·04
Carbonate of potash	0·38
Carbonate of lime	0·40
Carbonate of iron	0·21
Silica	0·54
	97·77

With traces of sulphate of lime, carbonate of magnesia, acetic acid, sugar, and colouring matter.

According to Gerber,† the jalap of commerce contains

Hard resin	7·8
Soft resin	3·2
Extractive	17·9
Gummy extractive	14·5
Colouring matter‡	8·2
Liquid sugar	1·9
Gum with salts	15·6
Mucilage	3·2
Albumen	3·9
Starch	6·0
Lignin	8·2
Malic acid	2·4
Chloride of potassium	0·5
Phosphate of magnesia	1·3
Phosphate of lime	0·4
Carbonate of lime	3·0
Water	4·8
	102·8

It is believed that the active principle of jalap resides in the resin. As to the jalappin mentioned in a preceding Chapter of this volume, it has been too imperfectly examined to determine its action.

14. *Gentian.* This is the root of the *gentiana lutea*, a plant which grows spontaneously in the mountainous parts of France, Switzerland, Hungary, &c. It is said to have been named after

* Jour. de Pharmacie, iii. 498. † Br. Arch. lxiii. 193.

‡ It assumes a fine red colour when acted on by the alkaline carbonates.

Gentius, a king of Illyria, who is supposed to have first discovered its virtues. The root is externally brown; internally yellow, with a spongy pith in the middle. Its taste is intensely bitter.

Gentian was analyzed in 1821, by MM. Henry and Caventou. They found in it

1 A very volatile odorous substance
2 Gentianite
3 Bird-lime or viscin
4 A greenish tallowy substance
5 Incrystallizable sugar
6 Gum
7 Brown extractive
8 Lignin.

They could detect no starch nor inulin, the process which they followed was nearly as follows.

They macerated the root for 48 hours in ether. The liquid assumed a yellow colour. It was decanted off and the greatest portion separated by distillation. When the residue cooled, a yellow crystalline mass was deposited, which adhered strongly to every thing with which it came in contact. The remaining ether from which this deposit had fallen was left to spontaneous evaporation, and the mass remaining was macerated in alcohol, of 0·83 specific gravity, as long as that liquid acquired any colour. The alcohol dissolved the gentianin, the odorous matter and the green fat, and left a semifluid colourless substance which was the *viscin*. It had neither smell nor taste, was insoluble in water, cold alcohol, acids, and dilute alkaline solutions. It was slightly soluble in boiling alcohol, and precipitated again when the liquid cooled. Ether dissolved it in every proportion. When distilled it passed over unaltered into the receiver.

Gentian has been more lately examined by M. Leconte, who has shown that the gentianin of Henry and Caventou is an acid, which has been already described under the name of gentisin, and that the bitter principle resides in a different substance not yet isolated. The distilled water of gentian deserves to be examined. When properly prepared it has a strong smell, a nauseous taste, and produces intoxicating effects. It is obvious, that the bitter principle of gentian is to be found in the aqueous solution of the root.*

15. *Valerian.* This is the root of the *valeriana officinalis*, a plant which grows abundantly in Great Britain. It was used by the ancients, and is described by Dioscorides under the name of Φου, and no doubt the Phu of Pliny was the same plant.

The roots of valerian are long and slender fibres issuing from the heads. It was first brought into estimation in convulsive affections by Fabius Columna, about the year 1592. He informs us that he cured himself of epilepsy, by means of the root of valerian. In this country it is a good deal used as an antispasmodic, and is rather a favourite remedy with many practitioners.

* Jour. de Pharmacie, xxiii. 465.

The roots of this plant should be dug up in autumn, when the leaves decay, and be preserved in a dry place. They have a strong peculiar unpleasant odour, and a warm bitter subacrid taste. It is well known that they are peculiarly grateful to cats.

Trommsdorf subjected this root to analysis. It loses $\frac{3}{4}$ths of its weight by drying. Distilled with water it yields a volatile oil, very liquid, and of a greenish-white colour. Its odour is strong and camphoric; its specific gravity, at the temperature of 77°, is 0·9340; its taste is aromatic and camphoric without being acrid. When exposed to the light it becomes yellowish. Nitric acid converts it into a resinous substance, or, if it be used in a sufficient dose, into oxalic acid. The expressed juice of the roots of this plant is muddy, and has a strong odour. It lets fall a portion of starch. It contains a peculiar substance approaching the nature of extractive, soluble in water, but insoluble in ether, and in pure alcohol. It is precipitated from water by the salts of lead, silver, mercury, and antimony. This juice contains also a portion of gum. The roots deprived of this juice yield a portion of black-coloured resin, but consist chiefly of lignin.*

16. *Horse-radish.* Einhoff has examined the root of this vegetable, the *cochlearea armorica*, and found that its acridity is owing to the presence of a small quantity of volatile oil, which he obtained by distilling the mashed roots in a water bath. A liquid came over, which was at first milky, but gradually deposited a little of the volatile oil in question. This oil had a pale yellow colour, and the consistence of the oil of canella. Its odour was that of horse-radish, excessively strong. Its taste was at first sweetish; but it left an acrid impression, and excited inflammation in those parts of the tongue and lips to which it was applied. It is heavier than water, with which it forms a milky liquid by agitation. It dissolves readily in alcohol. It is volatilized at the temperature of 60°. The liquid obtained from the roots of the horse-radish, by distillation, yielded traces of sulphur.†

17. *Elecampane.* The roots of the *inula helenium* or *elecampane* were examined by Rose, who extracted from them the peculiar vegetable principle called *inulin*. M. Funke afterwards subjected them to a new analysis, and obtained the following substances:—

A crystallizable volatile oil
Inulin
Extractive
Acetic acid
A crystallizable resin
Gluten
A fibrous matter (lignin?).‡

John subjected the same root to analysis,§ and obtained

* Ann. de Chim. lxx. 95. † Ibid. 185. ‡ Ibid. lxxvi. 98.
§ Chemische Untersuchungen, iii. 61.

Helenin	36·66
Mucilage	4·44
Extractive*	36·66
Soft resin	1·66
Wax	0·55
Camphor	0·41
Lignin	5·55
Insoluble extractive	13·88
Phosphate of potash, chloride of do. sulphate of do., with potash united to vegetable acids	2·08
Phosphates of lime and magnesia, lime united to vegetable acids, trace of phosphate of iron, silica	3·33
	105·22

18. *Sweet flag.* The roots of the *acorus calamus*, or *sweet flags*, have been subjected to analysis by Trommsdorf. According to him, 64 ounces of this root are composed of the following ingredients :—

	oz.	dr.	gr.
Volatile oil	0	0	13·33
Inulin	1	0	1
Extractive, with some muriate of potash	2	1	10
Gum, with some phosphate of potash	3	4	0
A viscid resin	1	4	0
Woody fibre	13	6	0
Water	42	0	35·67
	64	0	0†

19. *Andropogon schænanthus.* The root of this plant, from the isle of France, was examined by M. Vauquelin. It was found to contain, 1. A resin similar to that of myrrh. 2. A bitter colouring matter, soluble in water. 3. An acid. 4. Oxalate of lime. 5. Abundance of oxide of iron. 6. Much woody fibre.‡

20. *Aristolochia*§ *serpentaria*, or *snake-root birth-wort.* The root of this plant has been used in medicine, at least since the year 1632, and probably earlier. It is a native of Virginia. The root is perennial, and composed of a number of small fibres, proceeding from

* It had a bitter and acrid taste, and probably contained sugar.

† Ann. de Chim. lxxxi. 332.

‡ Ibid. lxxii. 302. M. Henry analyzed the root of the *Andropogon muriatus*, and found its constituents similar to those of the *A. Schænanthus*. See Jour. de Pharmacie, xiv. 57.

§ The name, *aristolochia*, occurs in Dioscorides, who informs us that there are three species, which he describes (lib. iii. cap. 4.). But as the *serpentaria* is a native of America, it is obvious that neither of his species can refer to it. The name is derived from the supposed virtue of the plant in cleansing the *lochia* after child-bearing. Hence the English name *birth-wort*, by which the *aristolochia clematis*, the only British species of this genus, is distinguished.

a common trunk, externally brown, and internally whitish. The dried root has an aromatic odour, not unlike that of valerian, and a sharp, bitter, pungent taste, having some analogy to that of camphor.

It is used as a diaphoretic, stimulating, and tonic medicine. It is useful in dyspepsia when the skin is dry and parched, and is believed to increase the efficacy of cinchona bark.

This root was analyzed by M. Chevallier, in 1820*, who obtained from it

1 A volatile oil, having the smell of the roots
2 Starch
3 Resin
4 Gum
5 Albumen
6 A yellow bitter substance, causing a feeling of irritation in the throat, and soluble in water and alcohol
7 Malate and phosphate of potash
8 A little malate of lime
9 Phosphate of lime
10 Iron
11 Silica.

21. *Aristolochia grandiflora* of Gomes; *aristolochia cymbifera* of Martius. The root of this plant, which is a native of Brazil, is used in that country as a medicine, and is distinguished by the Portuguese by the name of *Raiz de Mil homens* (*Root of a thousand men*). It is used as an antidote for the bite of a serpent, as an application to ulcers in the feet, burns, and also in cases of intermittent fever.

This root was examined in 1833 by M. Rudolph Brandes,† who extracted from it the following substances:—

1 An orange-yellow granular crystalline matter	1·2
2 An acid, like benzoic, probably new	0·5
3 Bitter extractive, with various salts	1·8
4 Green resin and wax	0·6
5 Sub-resin	1·2
6 Gum	1·4
7 Brown colouring matter, with sulphates and chlorides	1·7
8 Inulin	0·9
9 Phosphate of lime	0·3
10 Albumen	1·4
11 Lignin and moisture	89·9
	100·0

The *orange-yellow* matter was obtained by digesting the root in alcohol, distilling off the alcohol, and digesting the residue in water. The insoluble portion was treated with ether, a yellow solution was

* Jour. de Pharmacie, vi. 565. † Ann. der Pharm. vii. 285.

obtained, which, being left to spontaneous evaporation, the orange-yellow matter was deposited. It had a strong smell, similar to that of the root, had a balsamic and resinous taste, leaving an impression of bitterness. It had a granular consistency, and appeared imperfectly crystallized. When heated in a glass flask, it melted, and gave out smoke; by a higher temperature it distilled over in the form of empyreumatic oil. Easily soluble in alcohol and ether. Boiling water dissolves a very little of it. The alkalies dissolve it, letting fall yellow flocks.

22. *Asarum Europeum*, or *asarabacca*.* This plant, probably the ασαρον of Dioscorides, is a native of Great Britain, and has been long used in medicine. The leaves are usually employed, and are said to be emetic, cathartic, and diuretic. The root, in a coarse powder, when taken to the extent of about a scruple, acts as a gentle emetic.

The root is perennial, strong, divided, and fibrous. When dried it loses its emetic and cathartic properties altogether. This fact, first stated by Decandolle, induced MM. Lassaigne and Feneulle, to subject it to an analysis.† They obtained

1 A solid volatile oil
2 A very acrid fixed oil
3 A yellow matter, analagous to *cytisite*, in which the properties of the root reside
4 Starch
5 Mucus
6 Ulmin
7 Citric acid
8 Bicitrate and malate of lime
9 An acetate, an ammoniacal salt, and mineral salts.

23. *Columbo root.* This is the root of the *cocculus palmatus*, a diœcious plant, which grows abundantly in the forests of Mozambique, on the east side of southern Africa. The roots are dug up by the natives, in the month of March, and transported to Tranquebar, where they constitute a staple article of export with the Portuguese.

The dried root is brought to this country, packed in bags, and sometimes in cases. It is in transverse sections, generally about $\frac{1}{3}$d of an inch in thickness, and one or two inches in diameter. The bark is thick and easily detached, internally bright yellow, and covered with a wrinkled olive-brown cuticle. The inner part of the root is pale brown, and has a spongy texture, with dark converging rays. The pieces are frequently much perforated, evidently by worms.

This root has a slight aromatic odour, and a bitter taste. Planche analyzed it, and obtained a large proportion of a peculiar azotized substance, soluble in water, a yellow bitter resinous matter,

* The name *asarabacca* is made up of the words *asarum* and *baccharis*, two genera of plants, that seem to have been confounded together.

† Jour. de Pharmacie, vi. 561.

and one-third of its weight of starch. By repeated distillations he also obtained a volatile oil, and from the residue, malate of lime, and sulphate of lime. Wittstock discovered in this root a peculiar crystallizable principle, to which he has given the name of *columbin*. The method of obtaining this principle and its properties, have been already detailed in a preceding Chapter of this volume.

24. *Sarsaparilla.** This is the root of the *smilax sarsaparilla*, a native of South America, or rather of Mexico. It was brought to Spain about the year 1540, as an undoubted specific in syphilitic disorders, and as a powerful remedy in certain chronic diseases. But European practitioners did not find it to answer the character which it had acquired in Spanish America. It is still, however, employed, and considered as a valuable remedy in obstinate cases of syphilis.

The root is perennial, divided into several branches, which are somewhat thicker than a goose quill, straight, externally brown, internally white, and three or four feet in length. Humboldt informs us that it is smoked in the drying. It has no smell, but is distinguished by a mucilaginous, very slightly bitter taste. Canobbio analyzed it, and obtained

Acrid and bitter resin .	2·8
Gummy extract . . .	5·5
Starch	54·2
Lignin	27·8
	90·3

It has been analyzed also by M. Batka,† who obtained

1 A crystalline matter (*smilacin*)
2 A colouring crystalline matter
3 An essential oil
4 Gum
5 Bassorin
6 Starch
7 Albumen
8 Extractive
9 Gluten and gliadin
10 Lignin
11 Pectic acid
12 Acetic acid
13 Chloride of calcium, potassium, and magnesium
Carbonate of lime, oxide of iron and alumina.

It contains *columbin* and *smilacin*. The method of obtaining which, and their characters, have been detailed in a preceding Chapter of this volume.

25. *Ginger.* This is the root of the *amomum zingiber*, a plant which is a native of India, and was known to the ancients. Pliny

* A full account of the different varieties of sarsaparilla met with in commerce, is given by Batka, in Ann. der Pharmacie, xi. 305.

† Jour. de Pharmacie, xx. 43.

informs us that it was brought to Rome, in his time, from Arabia, and the country of the Troglodites. According to Rumphius, it came originally from that part of Africa which is adjacent to the Red Sea, and was called *zingiber* from *zingi*, the name applied to the inhabitants, because they were negroes; the word *zingi* signifying black. It has been long cultivated in the West Indies, and it is from that quarter chiefly that we are supplied with it.

The root is perennial, firm, knotted, of a compressed roundish form, beset with transverse rugæ, covered with ash-coloured bark, partly of a purplish tinge, and sends off many long fibres and offsets. The internal substance of the younger roots is softish, fleshy, and greenish; of the older it is compact, fibrous, whitish, and when powdered has a yellowish appearance.

When the stalks are entirely withered, which happens about the close of the year, the roots are in a proper state for digging. After being dug, they are picked, cleaned, and scalded in boiling water. They are then exposed to the sun till sufficiently dry, and packed into bags of 100 lbs. each, for the market. The roots thus prepared are called black ginger. White ginger is the roots of the same plant. But instead of being scalded, they are picked, scraped separately, washed and dried with great care. The very hot taste of this root, and the uses to which it is put as a seasoner of food, are too well known to require any farther notice here.

White ginger was analyzed by Bucholz,* who obtained

Volatile oil	1·56
Soft acrid resin	3·60
Extract soluble in absolute alcohol	0·65
Acidulous acrid extract, insoluble in absolute alcohol	10·50
Gum	12·50
Starch, or rather bassorin	19·75
Vegetable mucilage	8·30
Apotheme, soluble in potash	26·00
Lignin	8·00
Water	11·90
	102·76

The volatile oil was pale-yellow, very fluid, and had the smell of ginger. The extractive soluble in absolute alcohol, was soluble also in water, and had an acrid and hot taste.

It was afterwards analyzed by Morin,† in 1823, who obtained

Volatile oil
Acrid soft resin
Resin insoluble in ether and oils
Gum
Starch
Lignin

* Taschenbuch, 1817, p. 62. † Jour. de Pharmacie, ix. 253.

Vegeto-animal matter
Osmazome
Acetic acid, acetate of potash, sulphur.

The ash contained carbonate, sulphate, and muriate of potash, phosphate of lime, alumina, silica, iron, and manganese.

The vegeto-animal matter of Morin seems to be the same with the acrid acidulous extract of Bucholz.

26. *Manioc.* This is the root of *Jatropha manihot*, a plant of South America, from which the variety of starch called *tapioca* is obtained. This root contains a juice, which the American Indians employ for poisoning their arrows. It was examined in 1836, by MM. O. Henry and Boutron-Charlard,* and found to contain the following substances :—

1 Starch, known by the name of *cassava* and *tapioca*
2 Hydrocyanic acid. To which it owes its poisonous properties
3 A little sugar
4 Magnesia united to a peculiar acid, having an atomic weight of about 4
5 A bitter principle
6 A crystallizable fatty matter
7 Osmazome
8 Phosphate of lime
9 Lignin.

The acid, to which these chemists have given no name, crystallizes in prisms, has an acid taste, is soluble in water and alcohol, and melts when exposed to a gentle heat into a gummy-looking mass. It forms with lime, barytes, soda, and magnesia, crystallizable salts, which fuse easily, and are not poisonous.

27. *Peucedanum officinale.* This is a plant which grows wild in England, and is known by the name of *sea sulphur wort.* The root of it was formerly used in medicine, and preparations from it are still to be found in several of the foreign pharmacopæias. It was lately examined by Schlatter, who extracted from it a peculiar principle, to which he has given the name of *Peucedanin.* He obtained it in the following way :—

The root was digested in alcohol ; the tincture distilled to separate the alcohol ; and the residue left for some time to spontaneous crystallization. The mother water was then decanted off, and the crystals were washed with cold alcohol. They were then dissolved in boiling alcohol. When the solution cooled, transparent colourless needles were deposited, destitute of taste and smell, but the solution of which, in alcohol, had a very aromatic taste.

These crystals melt at 140°, without losing any weight. When the heat is increased they assume a tint of green, and then become greyish-white. They are insoluble in cold water. They melt in boiling water without dissolving. They are but little soluble in

* Jour. de Pharmacie, xxii. 118.

cold alcohol; but dissolve readily in that liquid when heated to 140°. The solution is precipitated by water. Peucedanin dissolves in the fixed and volatile oils. The concentrated acids decompose it, and the dilute acids do not dissolve it. It is soluble in the alkalies, and precipitated by acids. When assisted by heat it dissolves in carbonates of potash and ammonia, which allow it to be deposited in crystals on cooling. Its alcoholic solution is precipitated by acetate of lead, chloride of tin, and sulphate of copper, but not by sulphate of iron.* From these properties it appears more allied to the acids than the bases. It was analyzed in Liebig's laboratory, during the summer of 1837, and found composed of

4 atoms carbon . . .	= 3
2 atoms hydrogen . . .	= 0·25
1 atom oxygen . . .	= 1
	4·25

28. *Crameria triandra*, or *ratanhia*. The root of this plant, which is a native of South America, has been introduced into the materia medica of several Continental pharmacopæias, and is much employed, as yielding a very powerful and safe astringent matter.

The root is woody, hard, and round. It is covered with a thick bark, having a reddish-brown colour, and a bitter and astringent taste. The woody portion of the root is yellowish-white and tasteless. The active principles exist in the bark.

This root has been analyzed by Trommsdorf, Vogel, and C. G. Gmelin. It contains a species of tannin, which gives a green colour to the persalts of iron. Gmelin obtained

Tannin	38·3
Extractive with sugar . .	6·7
Mucilaginous azotic body . .	2·5
Starch	8·3
Lignin	43·3
	99·1

Trommsdorf found that 25 of the lignin was soluble in caustic potash, and consequently apotheme, and that its real amount was only 15 per cent. The crameric acid discovered by Peschier has been noticed in the *Chemistry of Inorganic Bodies* (vol. ii. p. 107). Some valuable observations on the medicinal preparations of this root, have been published by Subeiran† and Boullay.‡

29. *Punica granatum*, or *pomegranate tree*. The bark of the root of this tree was analyzed in 1824, by M. Mitouart, apothecary in Paris. It had been previously employed as a remedy for the tænia. He found it to contain tannin, a kind of wax, gallic acid in abundance, and a sweet-tasted substance, having the characters of

* Annalen der Pharmacie, v. 201.
† Jour. de Pharmacie, xix. 596. ‡ Ibid. xxi. 4.

mannite. It was analyzed again by M. Latour de Trie,* in 1831, who distinguished in it a peculiar substance, to which he gave the name of *grenadin*, and which he considered as essentially different from mannite. But MM. Boutron-Charlard and Guillemette have shown that its properties and constitution are absolutely identical with that substance.†

30. *Iris fœtidissima*. The root of this plant having been found useful by Dr Racamier, in dropsy, M. Lecanu was induced to examine its composition. He obtained

1 A very acrid volatile oil
2 Resin
3 A bitter principle
4 A yellowish-red colouring matter
5 Sugar
6 Gum
7 A free acid
8 Wax
9 Salts
10 Lignin.‡

31. *Liriodendron tulipifera*. The bark of the root of this tree, originally a native of America, but constituting at present a common ornament of our shrubberies, especially in the south of England, was examined chemically by Dr John P. Emmet, Professor of Chemistry and Materia Medica, in the University of Virginia. He discovered in it a peculiar principle, to which he has given the name of *liriodendrin*, and which he considers as intermediate between camphor and the resins.§

The fresh bark of the root of this tree has a pungent, aromatic, and bitter taste. When exposed for a few hours to the action of boiling water, or even to the light, its colour deepens, and it becomes brownish-red. The aqueous solution, on cooling, deposits a little liriodendrin in crystals.

The fresh bark contains so much pectate of potash, that its aqueous solution is too viscid to pass through the filter, unless it be precipitated by the diacetate of lead, or some earthy salt.

The easiest mode of obtaining liriodendrin, is to digest the fresh bark for five or six hours in alcohol, heated to 100°, in an opaque vessel. We obtain, in this way, a bitter-tasted solution, which, being filtered, and reduced by distillation to a fifth part of its bulk, lets fall impure liriodendrin when left at rest. Towards the end of the process, the bitter principle separates in drops of an amber colour, which become solid on cooling. The liquid is then evaporated to the consistence of honey, and a few drops of ammonia being added, the liriodendrin precipitates.

The liriodendrin thus obtained is washed with a solution of

* Jour. de Pharmacie, xvii. 503, 601.
† Jour. de Pharmacie, xxi. 169. ‡ Ibid. xx. 320. § Ibid. xvii. 400.

caustic potash, till water ceases to be coloured by it. In this state it contains water, and is softened by the heat of the hand. A temperature a little higher gives it an aromatic odour, and it melts like a resin. On cooling, it concretes into a brown substance, having a specific gravity of 1·097. Its taste is bitter and aromatic, but not strong, on account of its insolubility in water. The alcoholic solution is very bitter and acrid. But when the liriodendrin is crystallized, this acrid taste disappears. Dr Emmett obtained this substance in crystals, by the following process:—The resinous liriodendrin was dissolved in alcohol, the solution was heated to the temperature of 100°, and water of the same temperature was added slowly, till the liquid assumed a milk-white colour. It was then filtered and set aside. On cooling, the liriodendrin was deposited in crystals. These crystals were rendered quite pure by subjecting them to pressure between folds of blotting paper. In this way it is obtained in scales like boracic acid, or in needles, according to the slowness of its cooling. These crystals are transparent and colourless.

Liriodendrin thus crystallized, is scarcely soluble in cold water, but it communicates a bitter taste to hot water. Alcohol and ether are its best solvents. These solutions are colourless, and possess neither acid nor alkaline properties. Nitric acid dissolves it in great abundance without altering its colour, and it may be evaporated to dryness without alteration. Strong sulphuric acid dissolves it immediately, and assumes a deep reddish-yellow colour. The liriodendrin is converted into a resin which may be separated by water. Cold muriatic acid has little effect, but when assisted by heat it decomposes liriodendrin, and a green matter remains.

Iodine gives it instantly a yellow colour like that of chromate of potash. The most minute quantity of liriodendrin may be detected by this reagent.

Chlorine converts it into a bitter-tasted resin. When it is triturated with mucilage of gum arabic the bitter taste disappears, and when the solution is left at rest, it deposits crystals different from those of liriodendrin.

The crystals of liriodendrin melt when heated to 180°. At a little higher temperature it begins to sublime. A dense aromatic vapour rises and condenses into a transparent colourless varnish. The point of volatilization is so very near that of decomposition that we cannot volatilize it. When the crystals are heated in a glass tube, water separates from them before they melt. The products of the decomposition of this substance contain no traces of benzoic acid or ammonia.

32. *Iris latifolia* and *angustifolia*. The roots or *rhizomas* of these plants have been analyzed by M. Lecoq,* who obtained

* Jour. de Pharmacie, xiv. 221.

	In December.	In April.
Water . .	73·0	73·0
Fecula . .	12·5	10·8
Gum . .		
Sugar . .		
Tannin . .	1·5	3·2
Bimalate of lime		
Extractive .		
Albumen trace		
Lignin . .	13·0	13·0
	100	100

33. *Asparagus officinalis.* The root of this well known plant was examined by M. Dulong d'Astafort. He obtained

Albumen
Gum
A substance precipitated abundantly by subacetate of lead and nitrate of mercury
A resin
Sugar, reddened by sulphuric acid
Supermalates, Chlorides, Acetates, Phosphates } of potash and lime
Iron.*

34. *Convolvulus batata.* The root of this plant, which is a native of the West Indies, though it has been naturalized in Spain and the south of France, is used as an article of food. It was analyzed by M. O. Henry, who found it to contain

Starch	13·3
Water	73·12
Albumen	0·92
Incrystallizable sugar . .	3·30
Volatile poisonous matter .	0·05
Peculiar fatty matter . .	1·12
Parenchyma	6·79
Malic acid and salts . .	1·40
	100·00†

35. *Cornus florida.* The bark of the root of this tree, which is a native of North America, is used as a febrifuge. It was analyzed by M. Geiger,‡ who found it to contain

1 Cornic acid
2 Tannin
3 A peculiar resin, crystallizing and neutral

* Jour. de Pharmacie, xii. 278. † Ibid. xi. 233.
‡ Annalen der Pharmacie, xiv. 206.

4 Oxalate of lime, with another calcareous and magnesian salt, containing malic acid, and perhaps phosphoric
5 Two different colouring matters, the one soluble in acids, and insoluble in alkalies
6 Gum
7 A little starch.

CHAPTER VI.

OF BULBS.

By *bulbs* are understood tubercles connected with the roots of vegetables, very analogous to the *buds*, and containing the embryo of a future plant. The *potatoe* is a well known example of a bulb.

Several bulbs are composed of concentric coats, like the onion, while some are imbricated somewhat like the artichoke. Several bulbs, as the potatoe, onion, &c., are used as nutritive articles of food; while some, as the bulbous roots of the *colchicum autumnale*, constitute active medicines.

1. *Potatoes* are the bulbs of the *solanum tuberosum*, an American plant which is said to grow wild in the mountainous regions of Peru and Chili; and from the name, *Virginia potatoes*, applied to them when they began to be cultivated in the neighbourhood of London, one would suppose them to have been indigenous in North America, though this has not been confirmed by recent botanical travellers. They are said to have been first introduced into Ireland by Sir Walter Raleigh, in 1565; and from thence into England, by a vessel wrecked on that part of the west coast, called *North Meols*, in Lancashire. About the year 1605, they began to be cultivated in the neighbourhood of London, and were occasionally presented on the table as great rarities. In the year 1663, Mr. Buckland, a Somerset gentleman, wrote a letter to the Royal Society, recommending the planting of potatoes in all parts of the kingdom, to prevent famine. This was referred to a committee, who approved of the proposal, and agreed to recommend it with all the influence of the Society.* But many years elapsed before their cultivation in Great Britain became general. In France they may be said to have been brought into general use by the indefatigable exertions of Parmentier, about 1773. In Sweden they were recommended by a royal edict in 1764, and came very slowly into general use.

Potatoes have been repeatedly subjected to chemical examination. Parmentier published an elaborate dissertation on their culture,

* Birche's Hist. of the Royal Society, i. 213.

uses, and properties, about the year 1776, which contributed considerably to promote the cultivation of them on the continent. Dr Pearson contributed to the Board of Agriculture a valuable essay on potatoes, containing a set of chemical experiments on them, performed with his usual skill and ingenuity; and Einhof has published a very elaborate analysis of the root in the fourth volume of Gehlen's Journal.

The variety of potatoe which chiefly occupied the attention of Einhof, was that which has a red skin, and flesh-coloured juice. When dried by a moderate heat, till they ceased to lose any weight, potatoes were reduced to $\frac{1}{4}$th of their original weight.*

The analysis of this root was conducted by Einhof pretty much in the same manner as his analysis of barley and rye. A determinate quantity of potatoes was reduced with water to a pulp, and then washed on a searce till the liquid ceased to come off milky, or to hold any thing in solution. What remained on the cloth was the fibrous matter of the potatoe; but it differed essentially from the fibrous matter of most plants. With boiling water it formed a paste similar to that made by means of starch, and when dry it assumed a semitransparent appearance. This matter, when triturated in a mortar, and again washed with water, yielded a considerable portion of starch. The residue, which was of a light-grey colour, being triturated a second time, formed a powder, which bore a considerable resemblance to starch, both in its appearance and properties.

The liquid with which the potatoe was washed was at first milky, but deposited, on standing, a heavy white powder, which was *starch*. When filtered, it had a carmine-red colour, and reddened vegetable blues. When boiled, a flaky precipitate separated, partly white and partly red. This precipitate possessed the properties of albumen. The residue, evaporated to the consistence of an extract, had a brownish colour, was insoluble in alcohol and ether, soluble in water, and, according to Einhof, was a mucilaginous matter. The following were the proportions of these various substances, obtained from 100 parts of potatoes:—

Starch	15
Fibrous starchy matter . .	7
Albumen	1·4
Mucilage, in the state of a thick syrup	4
	27·4

To ascertain the nature of the acid which exists in potatoes, Einhof separated the juice of potatoes by a gentle pressure. He had first frozen and then thawed them, to facilitate the separation. Lime-water was added in excess to this liquid, and the precipitate was digested in diluted sulphuric acid, to separate the lime from the acid. Thus obtained, it was found to be a mixture of tartaric and

* Gehlen's Jour. iv. 457.

phosphoric acids.§ The sap, thus deprived of its acid, contained an excess of lime, in combination with the mucilage. Einhof found, that this lime became gradually saturated with carbonic acid, even though the sap was kept in close vessels; and that in process of time, if a sufficient quantity of lime were present, the mucilage acquired a sweet taste; and when treated with alcohol, a portion dissolved, which yielded crystals of sugar. This he considered as a conversion of the mucilage into sugar.

From 1820 parts of dried potatoes, Einhof obtained 96 parts of a greyish-white ash. Of these, 64 parts were soluble in water. They consisted chiefly of carbonate of potash; but contained likewise $10\frac{1}{4}$ parts of phosphoric acid, $3\frac{1}{2}$ of sulphuric acid, and 2 of muriatic. The insoluble 35 parts consisted of earths and oxides. From 20 parts of it he obtained

2·5 silica
6·0 lime
4·0 alumina
7·0 magnesia, with some manganese or oxide of iron

19·5

Einhof examined different kinds of potatoes. He found the same ingredients in all, but the proportions varied considerably.

The following table exhibits the constituents of different varieties of potatoes, according to the analyses of Einhof, Lampadius, and Henry, jun.

Kinds.	Starchy Fibrin.	Starch.	Albumen.	Gum.	Acids and Salts.	Water.
Red potatoe* .	7·00	15·00	1·40	4·1	5·1	75
Do. after budding*	6·80	15·20	1·30	3·7	—	73
The buds or germs*	2·80	0·40	0·40	3·3	—	93·1
Great red potatoe*	6·00	12·90	0·70	—	—	78
Kidney do.* .	8·80	9·10	0·80	—	—	81·3
Sweet do.† . .	8·20	15·10	0·80	—	—	74·3
Peruvian potatoe†	5·25	15·00	1·88	1·87		76
English do.† .	6·83	12·91	1·04	1·70		77·8
Onion do.† . .	8·38	18·75	0·9	1·66		70·3
Voichtland do.† .	7·13	15·41	1·25	1·95		74·3
Paris do.‡ . .	6·79	13·3	0·92		1·4	73·12

Besides the substances detected by Einhof and Lampadius, Vauquelin discovered, in the expressed juice of the potatoe, about 0·1

§ Though Einhof obtained phosphoric acid by the method described in the text, it does not follow that it existed in the potatoes in an uncombined state. It might have been in combination with lime, and held in solution in the potatoe juice by means of tartaric acid.

* Those marked * analyzed by Einhof.

† Those marked †, by Lampadius. Schweigger's Jour. ix. 362.

‡ Henry, junior.

per cent. of crystallized asparagin; about 0·4 or 0·5 per cent. of a substance containing azote, similar to gum, and not precipitated by tannin; a soft resin, which, when heated, emits an agreeable smell; an extractive substance, which becomes black when exposed to the air; citric acid; citrates of potash and lime, and phosphates of the same bases.*

Baup informs us, that potatoes, after they begin to grow, contain a small quantity of solanin.

As it may be useful to know the quantity of starch furnished by different varieties of potatoe, the following table drawn up from the experiments of Mr William Skrimshire, junior, is subjoined. Five pounds avoirdupois of fresh potatoes were used, and the starch was separated by grating the potatoe, and pouring water upon it placed upon a searce.†

Substances.	Varieties of Potatoes used.															
	Captain Hart.		Rough Red.		White Kidney.		Moulton White.		Yorkshire Kidney.		Hundred Eyes.		Purple Red.		Ox Noble.	
	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.
Fine starch . .	0	9	0	7¼	0	0	0	9	0	8¾	0	8¼	0	8	0	6½
Ditto, slightly coloured . .	0	3	0	3¼	0	9½	0	2¾	0	2½	0	0¾	0	0½	0	1¾
Pulp dried . .	0	6	0	6½	0	3¾	0	5¾	0	6½	0	6¾	0	5	0	8
Water, mucus, and extractive	3	14	3	15	4	2¾	3	14½	3	14¼	4	0¼	4	2½	3	15¾
Total . .	5	0	5	0	5	0	5	0	5	0	5	0	5	0	5	0

When potatoes are exposed to the action of frost, it is well known that they become soft, and acquire a sweet taste. This taste is succeeded by a sour taste, owing to the rapid evolution of acetic acid, and the root soon passes to putrefaction. From the experiments of Einhof, we learn that the sugar is formed at the expense of the mucilage; for the other ingredients were found, in potatoes sweetened by frost, in the usual proportions. He considers this sweetening process as connected with the vegetative powers of the root.

When potatoes are boiled, they lose from 1 to 1½ per cent. of their weight. The juice, which may be separated from them, is sweet-tasted. The meal is insoluble even in boiling water, though potatoe starch forms a transparent solution with hot water. Thus it appears, that by boiling, the albumen, fibrous matter, and starch combine together, and form an insoluble compound.‡

* Jour. de Phys. lxxxv. 113. † Nicholson's Jour. xxi. 71.

‡ Gehlen's Jour. iv. 485.

From these experiments, it appears that potatoes differ essentially from wheat and barley, by containing no gluten. They approach, in some measure, to the nature of rye.

Dr Peschier, of Geneva, has detected the presence of mucous sugar and of gum in the potatoe. This explains why they are capable of undergoing the vinous fermentation.*

2. *Jerusalem Artichoke.* This is the bulbous root of the *helianthus tuberosus*, a plant which grows wild in several parts of South America. It has somewhat the shape of a potatoe; but the tubers are smaller. They have a slightly sweet taste, and are very watery. The helianthus is very productive, and when once planted, they continue to grow in the same place, year after year, without any trouble whatever. An acre is said to yield from 60 to 70 tons of them.

We have three analyses of this valuable bulb; one by Zenneck in 1823;† another by Braconnot, in 1824‡; and a third by Payen, in the same year.§ Zenneck obtained

Green starch	6·5
Bitterish sweet extractive	1·4
Bitter and saline extractive not soluble in alcohol	4·0
Lignin	8·0
Albumen	0·4
Water with a little volatile oil	73·0
	93·3

Braconnot obtained

Water	77·2
Liquid sugar	14·8
Inulin	3·0
Vegetable skeleton	1·22
Gum	1·08
Citrate of potash	1·07
Peculiar substance‖	0·99
Ferruginous phosphate of lime	0·14
Sulphate of potash	0·12
Citrate of lime	0·08
Chloride of potassium	0·08
Phosphate of potash	0·06
Oil, very soluble in alcohol and potash	0·06
Cerin	0·03
Malate of potash	0·03
Silica	0·12
Tartrate of lime	0·07
	100·15

* Annals of Philosophy, xii. 337. † Schweigger's Jahrbuch, ix. 315.
‡ Ann. de Chim. et de Phys. xxv. 358. § Ibid. xxvi. 98.
‖ It produces viscous fermentation.

When the bulbous roots of the Jerusalem artichoke are bruized, and expressed, a mucilaginous liquid is obtained, having a specific gravity of 1·0995 as determined by Payen. This liquid is colourless, but speedily becomes brown when exposed to the air, but this is prevented by the addition of a little sulphuric acid. When heated to 212° it coagulates so strongly that it may be employed to clarify other liquids. The albumen thus deposited carries with it a little fixed oil, which may be separated by alcohol, and is composed of elain and stearin concreting at 60°. The alcohol at the same time dissolves a certain quantity of gluten. Payen found that the bulbous roots bruised and mixed with hot water and yeast ferment, and produce a quantity of anhydrous alcohol, amounting to 9 per cent. of the weight of the bulb employed.

3. *Garlic.* This is the bulbous part of the root of the *allium sativum*, a plant which grows spontaneously in Sicily, and is well known, and remarkable for its strong smell and peculiar taste. It was much celebrated by the ancients, both as an article of food and as a medicine. It has been repeatedly examined by chemists. The analysis of Neumann, considering the state of the art of examining vegetables at that time, must be considered as very exact.* Cadet has subjected it to a chemical examination.†

When dried, it loses nearly $\frac{2}{3}$ds of its weight; but this proportion is doubtless subject to considerable variation. The expressed juice of garlic is of a thick consistence like mucilage, and slightly reddens vegetable blues. When diluted with water, and filtered, it yields flakes of albumen when boiled. The residue consists chiefly of mucilage, of which garlic yields a very great proportion, and of extractive. This last is somewhat acrid in its nature. When garlic is distilled with water, it yields a portion of yellow-coloured volatile oil, at first lighter than water, but gradually becoming heavier as the distillation advances. To this oil garlic owes its most remarkable properties. Its taste is very acrid, and its smell strong. When applied to the skin, it produces an irritation not inferior to cantharides, and, like that drug, might be employed to blister the skin. When triturated with oxide of iron, it immediately strikes with it a black colour; but it has no effect upon any other metallic oxide.

When garlic is treated with alcohol, the liquid assumes a reddish-yellow colour, and leaves, when evaporated, a brown extract, very acrid, which attracts moisture from the air.

When garlic is distilled, it yields first a liquid slightly coloured, and having a very acrid taste; then a thick brown oil, and abundance of inflammable air and carbonic acid. The liquid in the receiver emits the smell of ammonia when mixed with lime. When 40,320 parts of garlic were incinerated, they left 4896 parts of ashes, or about $\frac{1}{8}$th of the original weight. From 172 parts of these ashes Cadet obtained the following substances:—

* Neumann's Chemistry, p. 481. † Ann. de Chim. lix. 106.

Potash	33·0
Sulphate of potash with some muriate	58·0
Alumina	2·0
Phosphate of lime	15·6
Oxide of iron	1·5
Magnesia	9·0
Lime	14·0
Silica	8·0
	141·1

From 1406 parts of fresh garlic he obtained

Mucilage	520
Albumen	37
Fibrous matter	48
Water, by estimate	801
	1406

Bouillon-Lagrange has detected in garlic, besides the acrid oil, a quantity of sulphur, starch, and saccharine matter.*

4. *Onion.* This is the bulbous root of the *allium cepa.* A few experiments on it had been made by Neumann and Cadet. But Fourcroy and Vauquelin published the first accurate analysis of it. When reduced to a pulp, and subjected to the press, it yields a viscid juice, somewhat opaque, at first colourless, but becoming gradually red in consequence of the oil which it contains. It has a strong smell, and reddens vegetable blues. It is precipitated by acetate of lead, lime water, oxalic acid, nitrate of silver, and potash. When distilled it yields a milky liquid, slightly acid, on the surface of which swim some drops of oil. It contains a little sulphur dissolved in the oil; for chlorine gives it the property of precipitating nitrate of barytes, and when distilled in a copper vessel some sulphuret of copper is formed. The portion of juice not distilled deposits a fawn-coloured sediment, having a strong oniony odour. Alcohol deprives this sediment of oil and of sulphur; the residue seems to possess properties analogous to those of gluten. The liquid, from which this precipitate has separated, contains phosphoric acid, sulphur, and gluten.

When onion juice is kept at a temperature between 60° and 70° it emits no gas, but it changes its colour successively to red and yellow, and lets fall a fawn-coloured sediment. It is now converted into vinegar still retaining the oniony odour; a proof that the volatile matter remains undecomposed. This vinegar contains in it a good deal of mannite, which readily crystallizes in needles. On examining recent onion juice no mannite could be found in it, merely a considerable quantity of uncrystallizable sugar. This sugar, in a heat between 60° and 70°, is gradually decomposed,

* Annals of Philosophy, xii. 36.

and converted into acetic acid and mannite. The fawn-coloured matter, which precipitated during this acetification, consisted of gluten, oil, and sulphur.

Onion juice is capable of undergoing the vinous fermentation. When 8 ounces troy were mixed with 122 cubic inches of water, and somewhat less than 1 ounce of barm, they underwent a brisk fermentation, and yielded by distillation about 2·35 ounces troy of strong alcohol. By Lavoisier's experiments 3·7 ounces of sugar would have yielded the same quantity of alcohol.

Besides the preceding constituents, Fourcroy and Vauquelin found in onion juice, mucilage, phosphate of lime, and citrate of lime.*

5. *Squill.* This is the bulbous root of the *scilla maritima*, a plant which is a native of Spain, Sicily, and Syria, where it grows in sandy situations by the sea-coast. It was known to the ancients, and is described by Dioscorides, both under the name σκιλλα and ταγκρατιον.†

The bulb is large, sometimes nearly the size of the human head, pear-shaped, and formed of fleshy scales, attenuated at both edges, and closely applied over each other. The roots are fibrous, and attached to a radical plate at the bottom of the bulb. Sometimes the bulb is white; but there is a variety in which the bulbs are red externally, though white within. Both are said to be equally good, though the red variety is preferred by apothecaries.

Squill has no smell; the taste is bitter, nauseous, and acrid, and when much handled, it inflames and ulcerates the skin. It is employed in medicine as a diuretic, and to excite nausea and vomiting. It has been subjected to a chemical examination by Vogel, and was found by him to owe its peculiar properties to a species of bitter principle which he distinguished by the name of *scilitin*, which has been described in a preceding Chapter. From dried squills he extracted the following substances:—‡

Gum	6
Scillitin	35
Tannin	24
Citrate of lime	
Sugar	
Woody fibre	30

6. *Colchicum autumnale*, or *meadow saffron.* The bulbous root of this plant was introduced into medicine by Baron Stoerck, and has been much used of late years as a remedy for the gout, being supposed to constitute the basis of the *eau medicinale* of Husson. It is a native of Britain, and abounds in Essex and Suffolk, and in some parts of Germany, in rich meadow ground. The leaves appear in spring, and the flowers in autumn, after the leaves have disappeared.

The bulb is solid, egg-shaped, and covered with a brown mem-

* Ann. de Chim. lxv. 161. † Lib. ii. cap. 203. ‡ Ann. de Chim. lxxiv. 147.

branous coat. The thick old bulb begins to decay after the flower is perfectly expanded, and the new bulbs, of which there are always two on each old bulb, are perfected in the following June, from which time, till the middle of August, they may be taken up for medicinal use.

The bulbs, when ripe, on being cut transversely, yield a milky acrid juice, which strikes a fine blue colour, with an alcoholic solution of guaiacum. To preserve the virtues of the plant, the bulb, as soon as possible after being dug up, should be cut into slices, not thicker than $\frac{1}{8}$th of an inch, and dried separately on blotting paper, without heat, and at a low temperature. The test of the drug being good, and properly dried, is the appearance of the blue colour, on rubbing it with a little vinegar and alcoholic solution of guaiacum.

The recent bulbs have scarcely any smell. The taste is bitter, hot, and acrid, occasioning a feeling of heat in the stomach, when taken even in small quantity. It is poisonous. It was analyzed by Pelletier and Caventou in 1820, and found to contain the same alkaline substance, veratrina, which they had already detected in the *veratrum sabadilla*, and *veratrum album*.

They obtained the following constituents from the bulbs of the *colchicum autumnale*:—*

Fatty matter, composed of elain, stearin, and volatile acid
Bigallate of veratrina
Yellow colouring matter
Gum
Starch
Inulin, in abundance
Lignin.

Stoltze collected the bulbs of the *colchicum autumnale* in March, and obtained from them

Acrid volatile matter	trace
Soft resin	0·04
Crystallizable resin	0·41
Sweet and bitter extractive	5·91
Difficultly soluble extractive	1·30
Gum, like gum tragacanth	0·81
Starch	7·46
Lignin	2·32
Extractive, soluble in potash	0·61
Water	81·04
	99·90†

From the bulbs of the same plant, collected in autumn, he obtained

* Ann. de Chim. et de Phys. xiv. 82.
† Berl. Jahrb. xix. 107.

Acrid volatile matter, rather more	
Soft resin	0·06
Crystallized sugar	1·12
Uncrystallizable sugar	2·72
Bitter extractive	2·17
Difficultly soluble extractive	0·52
Tragacanth-looking gum	1·65
Starch	10·12
Lignin	1·61
Extractive, soluble in potash	0·52
Water	80·31
	100·80*

The bitter extractive of Stoltze doubtless contained the veratrina found by Pelletier and Caventou.

7. Tubercles of *lathyrus tuberosus*. This plant is cultivated in Holland, where the tubercles are used as an article of food. They are called by the French *macjon*. The constituents of these tubercles, according to the analysis of Braconnot, are as follows:—

Water	65·6
Starch	16·8
Common sugar	6·0
Lignin	5·04
Animalized matter	3·00
Albumen	2·80
Oxalate of lime	0·36
Rancid oil, Adipocire	0·18
Phosphate of lime	0·10
Sulphate of potash	0·04
Malate of potash	0·04
Phosphate of potash	0·02
Muriate of potash	0·02
Odorous principle	—
	100·00†

8. Bulbs of the *oxalis crenata*. These bulbs, according to the analysis of Payen, contain

Water	86
Starch	2·5
Albumen	1·5
Mucilage and salts	5·55
Lignin and silica	4·44
	100·0‡

He afterwards found, that in other specimens the proportion of starch was greater.

* Berl. Jahrb. xx. 135. † Annals of Philosophy, xiii. 70.
‡ Ann. der Pharmacie, xv. 160.

From the stems of the same plant Payen obtained

Water	95·2	to 88·6
Lignin	2·05	— 5·0
An oxalate	1·06	— 1·23
Albumen	0·40	— 0·75
A soluble substance, containing azote	0·60	— 0·75
Chlorophylle	0·06	— 0·10
Oxalate of ammonia, acid salts, gum, and aroma	1·23	— 2·00
	100·60	98·43*

CHAPTER VII.

OF WOODS.

THE *wood* of different trees differs materially in hardness, strength, durability, and beauty. But from the experiments of Count Rumford, there is reason to believe that the mere woody fibres of all plants are nearly the same, and that the differences are owing almost entirely to the various proportions of liquids and empty spaces with which the woody fibres are intermixed. He found the specific gravity of the wood of different trees as follows:—

Poplar	1·4854
Lime	1·4846
Birch	1·4848
Fir	1·4621
Maple	1·4599
Beech	1·5284
Elm	1·5186
Oak	1·5344

A cubic inch of oak and poplar consisted respectively of the following proportions of wood, sap, and air:—

	Wood.	Sap.	Air.
Oak	0·39353	0·36122	0·24525
Poplar	0·24289	0·21880	0·53831

He found likewise that the same tree in winter contains more sap than in summer; and that in summer it contains more air than in winter.†

MM. Petersen and Schödler made an important set of experiments on the analysis of the different kinds of wood, in Liebig's laboratory, in 1835,‡ in order to determine their relative value as firewood. The wood of the different trees (just as they had been

* Ann. der Pharmacie, xv. 160. † Nicholson's Jour. xxxiv. 319.
‡ Ann. der Pharm. xvii. 139.

felled) was reduced to a fine powder, dried at 212°, mixed with oxide of copper, and analyzed in the usual way. From the quantity of water and carbonic acid obtained, the hydrogen was estimated, and the oxygen was calculated from the deficiency. In these experiments the small quantity of ash left (about 0·2 per cent.) was neglected. It of course increases the oxygen in that small proportion. The following table shows the results obtained:—

Woods.	Carbon.	Hydrogen.	Oxygen.
Quercus robur	49·432	6·069	44·499
Fagus sylvatica, *a.* Red	48·184	6·277	45·539
Ditto *b.* White	48·533	6·301	45·166
Betula alba	48·602	6·375	45·023
Betula alnus	49·148	6·217	44·587
Pinus larix	50·106	6·310	43·584
Pinus abies	49·946	6·407	43·647
Pinus picea	49·591	6·384	44·025
Pinus sylvestris	49·937	6·250	43·813
Prunus domesticus	49·311	5·964	44·725
Prunus cerasus	48·824	6·276	44·900
Pyrus malus	48·902	6·267	44·831
Pyrus communis	49·395	6·351	44·254
Diospyros ebenum	49·838	5·352	44·810
Buxus sempervirens	49·368	6·521	44·111
Ulmus suberosa	50·186	6·425	43·389
Populus nigra	49·699	6·312	43·989
Fraxinus excelsior	49·356	6·075	44·569
Juglans regia	49·113	6·443	44·444
Robinia Pseudacacia	48·669	6·272	45·059
Tilia Europæa	49·408	6·861	43·731
Æsculus hypocastanum	49·077	6·714	44·209
Salix fragilis	48·839	6·360	44·801
Acer campestris	49·803	6·307	43·890

The *vegetable fibres* in herbaceous plants correspond with the *wood* of trees. In some it is so brittle as to be easily broken, while in others it is flexible and tough; as in *hemp*, *nettles*, *lint*, &c., but in these perhaps the fibres ought to be considered rather as the *liber* or inner bark, than the wood.

To separate hemp and flax from the stems which contain them, the plants are steeped in stagnant water, till they undergo a species of putrefaction, which destroys the glutinous matter which cements the fibres to the plant. They are then spread upon the grass till they become quite dry. By these processes the stalks are rendered very brittle, (*all but the fibres*) and when passed between rollers and struck by scutches, the whole vegetable matter is driven off, and nothing remains but the hemp or lint, in the state of grey-coloured and tough fibres. These fibres are afterwards bleached white.

Mr James Thomson and Mr Bauer have shown that the fibres

of flax are transparent cylindrical tubes, articulated and pointed like a cane: while the filaments of cotton are transparent glassy tubes, flattened and twisted round their own axis. A section of a filament, resembles, in some degree, the figure 8, the tube originally cylindrical, having colapsed most in the middle, forming semitubes on each side, which give to the fibre, when viewed in certain lights, the appearence of a flat ribbon with a hem or border on each edge. The uniform transparency of the filament is impaired by small irregular figures, probably wrinkles arising from the desiccation of the tube.* In consequence of this difference between the structure of linen and cotton fibres, Mr Thomson and Mr Bauer were enabled to ascertain, that the cloth in which the Egyptian mummies are wrapt, is always linen and never cotton. It is clear from this, that the opinion entertained by some, that what is called in our translation of the Old Testament *fine linen* of Egypt, ought to be fine *cotton cloth* of Egypt is erroneous. We have no evidence from the cloth wrapt about ancient mummies, that the Egyptians in these early times were acquainted with cotton.†

Cotton is a soft down which envelops the seeds of various plants, especially the different species of *gossypium*, from which the cotton of commerce is procured. These plants are natives of warm climates; grow wild in Asia, Africa, and America, within the tropics; and are cultivated in the East and West Indies. The finest cotton, according to Mr Edwards, is distinguished by the name of *green seed cotton*, from the colour of its seeds,‡ and is perhaps the produce of the *gossypium hirsutum*. There are two species of it; in one of which the cotton does not easily part from the seeds. But the cotton plant commonly cultivated is a shrub, of which Mr Edwards enumerates five kinds; namely, the *common Jamaica*, the *brown bearded*, the *nankeen*, the *French* (*gossypium arboreum*), and the *kidney cotton*.§ When the seeds are ripe, the pods open and display the cotton, which is collected and separated from the seeds by means of rollers.

Cotton, when spun and woven into cloth, furnishes garments to a very considerable portion of the civilized world. The quantity annually brought into this country, and spun by machinery, is not less than 60,000,000 of pounds; and the number of individuals employed in manufacturing it cannot be fewer than 2,000,000. It constitutes therefore one of the most important of our manufactures.

Cotton is tasteless and destitute of smell. It is completely insoluble in water, alcohol, ether, and oils, and in all the vegetable acids.

The diluted alkaline leys have no perceptible action on cotton; but when very strong, they dissolve it if assisted by a sufficient

* Phil. Magazine, (3d series) v. 355, for 1834.

† The Hebrew word for linen cloth is סדין, hence the σινδων of the Greeks.

‡ History of the West Indies, ii. 264.

§ Perhaps the first species are only varieties of the *gossypium herbaceum*.

degree of heat. The new products obtained by this solution have not been examined.

Cotton has a strong affinity for some of the earths, especially for alumina. Hence this substance is used to fix colours on cotton. The cloth is steeped in a solution of alum or acetate of alumina, and afterwards dyed.

Several of the metallic oxides also combine with it readily, and remain united with much obstinacy. Oxide of iron is one of the most remarkable. When cotton is dipped into a solution of iron in an acid, it comes out yellow, and the iron is neither separated by alkalies nor soap, nor even by acids, unless when the combination is recent. The colour gradually deepens by exposure to the air, owing no doubt to the oxidizement of the iron, unless the cloth be steeped in an aluminous solution, which prevents the colour from becoming disagreeable, probably by diluting it.* Oxide of tin also combines with cotton, and is frequently used as a mordant.

Cotton combines readily with tannin, and forms a yellow or brown compound. Hence the infusion of galls, and of other astringent substances, is often used as a mordant for cotton. Nitric acid decomposes cotton when assisted with heat, and oxalic acid is formed; the other products have not been examined. Sulphuric acid likewise chars it. Chlorine gas bleaches it, and probably alters and dissolves it when applied in a concentrated state. Cotton is extremely combustible, and burns with a clear lively flame. The ashes left behind, according to Neumann, contain some potash. When distilled it yields a great portion of acidulous water, and a small quantity of oil, but no ammonia.†

Paper is prepared from hemp, linen, and cotton rags. These rags are bleached, reduced to an impalpable pulp. This pulp is spread equally by means of water on a wire gause frame, which allows the water to run off. The paper then is left to dry. To render it fit for writing upon, the pores which it naturally contains must be filled up. This is accomplished by dipping each sheet into a solution of glue and alum, an operation which is called *sizing*. This renders the paper impenetrable to liquids. Filtering paper must not be sized. Much of the white coarse paper made in this country is filled up with sulphate of lime, which gives it an appearance of much greater strength and thickness than it really possesses. Such paper cannot be employed for filtering. 40 grains of good filtering paper contains at an average $\frac{1}{3}$d of a grain of ashes. But in some of the paper made up with sulphate of lime, I have found as much as 17 grains of residue in 40 grains of the paper. Silk paper is very light but contains much ashes. The light red-coloured blotting paper, so common in this country, is a cotton paper formed from the rags or shreds of turkey-red cloth. It owes its red colour to the madder dye.

Paper, such as we use at present, was unknown to the ancients.

* See Chaptal, Ann. de Chim. xxvi. 266. † Neumann's Chem. p. 430.

It seems to have been an Arabian invention. It is supposed that the Arabians were acquainted with paper, from cotton rags, as early as the year 704. But the art was known and practised at a much earlier date in China. From the researches of Montfauçon, we learn, that cotton paper was used in Europe as early as the end of the ninth century.

The only kinds of wood which have been subjected to chemical experiments, are those which are employed in dyeing. For an account of these the reader is referred to a previous Division in this volume, in which these different woods are described in detail.

But as wood is much employed for fuel, the following table from the experiments of MM. Peterson and Schödler showing the quantity of oxygen required for burning 100 parts of various kinds of wood is important, as this oxygen is proportionable to the quantity of heat evolved by each.*

Names of Trees.	Oxygen to burn 100 of each.
Tilia Europea, *lime* . .	140·523
Ulmus suberosa, *elm* . .	139·408
Pinus abies, *fir* . . .	138·377
Pinus larix, *larch* . .	138·082
Æsculus hippocastanum, *horse-chesnut*	138·002
Buxus sempervirens, *box* .	137·315
Acer campestris, *mapple* .	136·960
Pinus sylvestris, *Scotch fir* .	136·931
Pinus picea, *pitch pine* .	136·886
Populus nigra, *black poplar* .	136·628
Pyrus communis, *pear tree* .	135·881
Juglans regia, *walnut* . .	135·690
Betula alnus, *alder* . .	133·959
Salix fragilis, *willow* . .	133·951
Quercus robur, *oak* . .	133·472
Pyrus malus, *apple tree* .	133·340
Fraxinus excelsior, *ash* .	133·251
Betula alba, *birch* . .	133·229
Prunus cerasus, *cherry tree* .	133·139
Robinea pseudacacia, *acacia*	132·543
Fagus sylvatica, *white beech*	132·312
Prunus domestica, *plum* .	132·088
Fagus sylvatica, *red beech* .	130·834
Diospyros ebenum, *ebony* .	128·178

* Ann. der Pharmacie, xvii. 144.

CHAPTER VIII.

OF PITH.

What is called the *pith* is a whitish elastic tissue in the centre of the stem and branches of dicotyledonous trees. It is composed of vesicles, which while the plant is very young are filled with a liquid. But as the plant advances, this liquid disappears and the pith becomes dry. It would appear from this, that the pith is only essential during the early part of the life of trees. The volume of pith is sometimes very inconsiderable, at other times it occupies a great portion of the stem or branch as in the elder.

The pith is commonly white, loose, elastic, light, and full of cells, so that it may be compressed into a small bulk. It generally swims on the surface of alcohol. According to John, it gives out ammonia when distilled; but Link could not obtain any by this process. When held to the flame of a candle it catches fire, and burns with flame. Sulphuric acid blackens and dissolves it, and the solution is precipitated black by water. Nitric acid dissolves it and converts it into oxalic acid, without the smallest trace of suberic acid appearing. The alkaline hydrates and carbonates do not dissolve it. It is insoluble in water, alcohol, ether and oils both fixed and volatile.

Dr John has distinguished the pith of the *helianthus annuus* (the *sunflower*), the *syringa vulgaris*, &c., by the name of *medullin*.

According to him it is distinguished by the following properties:

1. It is insoluble in water, ether, alcohol, and oils.
2. It is destitute of taste and smell.
3. Its structure is peculiar, being full of pores.
4. It is soluble in nitric acid; but instead of forming suberic acid, as is the case with suber, it furnishes a quantity of oxalic acid.
5. When distilled it furnishes a considerable quantity of ammonia, and leaves a charcoal having a metallic appearance and a colour similar to that of bronze.*

CHAPTER IX.

OF LEAVES.

The leaves of plants bear a greater resemblance to each other than any of the parts already treated of. They are covered only with an epidermis; the cortical layers of the bark being wanting. Below

* John's Chemische Taballen der Pflanzen Analysen, p. 9.

the epidermis is a pulpy matter, usually green, which contains a resinous substance and a portion of gluten. Below this is the fibrous matter, or rather the vessels which form the outline of the leaf. Alcohol extracts the green colouring matter of leaves, and so do oils but not water. It is remarkable, that even those leaves which are not green still give a green tincture to alcohol. The green colour soon fades when exposed to air, either in solution or separated by evaporation.* Many leaves give a yellow colour to cloth, which may be fixed by means of alum. Hence the much greater number of yellow dyes than of any other colour. The leaves of woad (*reseda luteola*) are those which give the finest yellow, and they are much employed by the dyers on that account.

1. *Senna.* This valuable cathartic is the dried leaves of the *cassia senna* or more probably of the *cassia acutifolia* and *cassia obovata*, annual plants which grow in Upper Egypt, and in Nubia. The leaves are pinnated: the leaflets, of which there are about five pair, are sessile, oblique at the base, oval, pointed, scarcely an inch in length, and rather more than a quarter of an inch in breadth, and of a yellowish-green colour. The best senna grows wild, and yields two crops of leaves, the first in September, and, the second in the following March. The plants are cut when the flowers begin to fall and exposed on the rocks to dry in the sun.

The leaves are picked, packed in bales, and sent to Boullac, the great entrepôt of senna, where they are mixed with two other species of cassia, the *cassia senna* of Forskal, and the *cassia angustifolia* of Wildenow. The proportions, according to Dr Calloden, are 500 parts of *cassia angustifolia*, 300 of *cassia senna*, and 200 of the *cynanchum oleifolium*. The leaves of this last plant must be considered as an adulteration.

The smell of senna is rather disagreeable. Its taste is slightly bitter, aromatic, sweetish and nauseous. Its virtues are extracted by hot water. The infusion has a deep reddish-brown colour, and possesses the smell and taste of the leaves. It is usually administered under that form. The decoction is bad, because boiling impairs the cathartic activity of the medicine.

Senna seems to have been first employed as a medicine by the Arabian Physicians, Serapion and Mesue, who are supposed to have lived towards the end of the tenth century, the first of the Greeks by whom it is noticed, is John Actuarius, who lived in the thirteenth century, as he dedicates his book *On the Action and Affections of the Animal Spirit*, to his master, Joseph Ratzendites, who lived under the reign of Andronicus II., Palæologus who died in the year 1332.

Senna was examined many years ago by Bouillon Lagrange. He conceived that the active principle resided in an extractive matter, soluble in water, and converted into a species of resin by absorbing oxygen.† It was subjected to a new examination in 1821, by MM. Lassaigne and Feneulle,‡ who found in it a peculiar sub-

* Lewis, Neumann's Chem. p. 434. † Ann. de Chim. xxvi. 3.
‡ Ann. de Chim. et de Phys. xvi. 16.

stance, which they distinguished by the name of *cathartina*. To this substance senna is indebted for its cathartic properties. It is probably an alkali, and has been described already in a former part of this volume, when treating of the vegetable alkaline bodies. The constituents extracted from senna, by Lassaigne and Feneulle were the following:—

1 Chlorophylle
2 A fat oil
3 A little volatile oil
4 Albumen
5 Cathartina
6 Yellow colouring matter
7 Mucilage
8 Malic acid
9 Malate and tartrate of lime
10 Acetate of potash
11 Mineral salts.

2. *Belladonna.* The substance employed in medicine under the name of *belladonna* is composed of the dried leaves of the *atropa belladonna* or *deadly night-shade*, a plant which is indigenous in Great Britain. The leaves of this shrub are lateral, in pairs of unequal size, decurrent, on short petals, egg-shaped, pointed, entire, of a dusky-green colour above, and paler below, soft and fatty to the touch. These leaves have no smell. The taste is slightly nauseous, sweetish and subacrid. They do not lose their active properties when dried. Every part of the plant is poisonous.

Whether our belladonna be the *strychnon* of the ancients has not been determined. But from the description which Pliny* gives of the intoxicating effects which it produces when taken into the stomach, the opinion that the two names apply to the same plant is not unlikely to be true. The symptoms are, intoxication accompanied by violent laughter, and violent gestures, great thirst, difficulty of swallowing, nausea, dilatation of the pupil of the eye, with the eyelids drawn down, redness and tumefaction of the face, stupor or delirium, a low feeble pulse, paralysis of the intestines, convulsions and death.

The leaves of this plant were examined by Melandri. He found in them oxalate of magnesia with excess of acid, oxalate of lime, muriate of potash, a soft green-coloured resin, mucus, extractive, and a substance which Melandri called animal extractive, no doubt analogous to gluten or albumen.† The leaves of this plant were examined likewise by Vauquelin. He obtained from them the following constituents:—

1. Vegetable albumen, or gluten
2. A bitter nauseous substance, which constitutes the narcotic part of the plant
3. Nitrate, muriate, sulphate, superoxalate and acetate of potash.‡

* Hist. Natur. lib. xxii. cap. 31. † Ann. de Chim. lxv. 222. ‡ Ibid. lxii. 53.

In 1819 it was analyzed by Brandes, who discovered in it a vegetable alkali, to which it owes its peculiar properties, and which he distinguished by the name of *atropina*. He obtained from the leaves of belladonna, the following constituents:—

Wax	0·7
Chlorophylle	5·84
Pseudotoxin*	16·05
Phytocolla†	6·90
Gum	8·33
Starch	1·25
Albumen	10·70
Lignin	13·70
Salts‡	7·47
Water	25·80
	96·74

Some years ago, M. T. Schmidt of Berlin, observed crystals in the extract of belladonna. He mentioned the circumstance to M. Blitz, of Erfurd, who ascertained that these crystals consisted of asparagin.§

Atropina has been described among the vegetable alkalies in a preceding Chapter of this volume.

3. *Tobacco.* This substance is formed from the leaves of the *nicotiana tabacum*, a plant which is a native of Virginia, where it is cultivated very extensively for the purposes of commerce. Its name was given it from Tabaco, a province of Mexico, where it was first observed, and whence it was originally brought to Europe.‖

Tobacco, when properly cured, has a yellowish-green colour, a strong and rather unpleasant smell, and a very acrid taste. When burnt it emits a strong odour, which to many is peculiarly grateful. When swallowed, it acts very violently upon the system; and when taken in sufficient quantity, proves fatal. Vauquelin subjected the leaves of different species of *nicotiana* particularly the *latifolia*, to analysis. The expressed juice contained the following substances:—

A considerable quantity of vegetable albumen or gluten
Supermalate of lime
Acetic acid
A notable quantity of nitrate and muriate of potash

* This is a substance soluble in alcohol, and containing azote. It was not free from salts, among which were malate of atropina, with oxalate, muriate, and sulphate of potash.

† This is a substance insoluble in alcohol and containing azote.

‡ The salts were malate of atropina, and sulphates, nitrates, phosphates, acetates, and muriates of potash, ammonia, lime, magnesia.

§ Jour. de Pharmacie, xxi. 178.

‖ For a detailed account of the culture and management of tobacco, see Tatham's Essay on its culture and commerce, published in 1800. The tobacco of Schiraz, in Persia, is most highly esteemed of all. It has been described by Mr Lindlay, as a new species under the name of *nicotiana Persica*. See Horticultural Trans. (new series), i. 205.

A red matter soluble in alcohol and water which swells considerably when heated
Muriate of ammonia
Nicotina
Green fecula composed chiefly of gluten, green resin, and woody fibre.*

The most recent analysis of the leaves of this plant is by MM. Posselt and Reinmann.† They obtained

Nicotina	0·06
Nicotianin	0·01
Extractive slightly bitter	2·87
Gum, with a little malate of lime	1·74
Green resin	0·267
Albumen	0·26
Gluten	1·048
Malic acid	0·51
Malate of ammonia	0·12
Sulphate of potash	0·048
Chloride of potassium	0·063
Malate and nitrate of potash	0·095
Phosphate of lime	0·166
Malate of lime	0·242
Silica	0·088
Lignin	4·969
Starch, a trace	—
Water	88·280
	100·956

4. *Digitalis purpurea*, or *Fox-glove*. The leaves of this indigenous plant, too common to require any description, were introduced into the Materia Medica by Dr Withering, as a diuretic. It had been used before occasionally as a sedative. But its diuretic properties, for which at present it is chiefly valued, seem to have been discovered by Dr Withering.

The leaves should be gathered when the plant is in flower, and those only selected which are fresh. The leafstalks and midribs should be rejected, and the leaves dried by exposure to the sun, or hung up separately till they dry in a warm kitchen.

When fresh they have no smell; but when dried acquire a weak narcotic odour, and have a bitter nauseous taste. Both water and alcohol extract their virtues. The dried leaves should have a beautiful green colour. When triturated with lime they give out ammonia. These leaves have been analyzed by MM. Rein and Haase, and still more lately by Welding.‡ He obtained

1 Gallic acid
2 Mucus

* Ann. de Chim. lxxi. 139. † Mag. Pharm. xxiv. 138, and xxv. 2, 57.
‡ Ann. der Pharmacie, xiii. 212.

3 Red colouring matter, soluble in water, but not in ether or alcohol
4 Chlorophylle
5 Sugar
6 Starch, a trace
7 Volatile oil
8 A fixed flocky substance
9 Gum
10 A fatty substance
11 Extractive
12 Digitalin
13 Lignin.

According to Haase, the active principle of fox-glove resides in the soft resin. But Le Royer has announced in it a peculiar principle, which he has called *digitalina*, and which probably possesses alkaline properties. But the accuracy of this statement has been called in question by Brault and Poggiale. According to these chemists, the substances extracted from the leaves of digitalis are

1 Chlorophylle
2 Resin
3 Fatty matter
4 Starch
5 Lignin
6 Gum
7 Tannin
8 Salts of lime and potash
9 A volatile oil
10 A fixed oil
11 Oxalate of potash.*

5. *Tea.* This substance, so much used in Great Britain as an article of food, is composed of the dried leaves of the *thea bohea* and *thea viridis*, plants which grow in the mountainous regions of China and in Japan. There are a great many varieties of tea; but it is the opinion of botanists that they are all the produce of the two species above mentioned. The leaves of the *thea bohea* are larger than those of the *viridis*. The *viridis* is a hardy shrub, and even capable of bearing the summer temperature of the neighbourhood of London in the open air. The *thea bohea* is a more delicate plant, and requires the shelter of a green-house.

Tea was introduced into Europe by the Dutch East India Company, and was first brought into England about the year 1666, and was sold at the rate of sixty shillings per pound weight. For many years the price was so high as to confine its use to people of opulence. Of late years, since the China trade was thrown open, the price of tea has sunk considerably, and the consumption of it has increased enormously. In 1794 the consumption in Great Britain was 20,000,000 lbs.; now it is not under 50,000,000 lbs.

* Jour. de Pharmacie, xxi. 133.

The leaves are not fit to be pulled till the shrub has vegetated for three years. When the tea leaves have been collected, they are exposed to the steam of boiling water. Every leaf is then rolled up by the hand, and they are put upon plates of copper and held over the fire till they become dry and shrivelled. It is to this heating process that tea owes its peculiar flavour.

Tea leaves were analyzed by Frank, in 1798.* When distilled with water it loses all smell, and the product of the distillation exhibits traces of a volatile oil. The aqueous solution contains gum and tannin, which blackens the salts of iron. Bohea tea contains more tannin than green tea. From the residue, exhausted by water, caustic potash extracts albumen. Bohea tea contains

Tannin	40·6
Gum	6·3
Albumen	6·4
Lignin	44·8
	98·1

Green tea contains

Tannin	34·6
Gum	5·9
Albumen	5·7
Fibrin	51·3
	97·5

Oudry has lately announced that he has discovered in tea a salifiable base, to which he has given the name of *theina*. The properties of this substance, and its identity with caffein have been stated in a preceding Chapter of this volume.

6. *Ledum latifolium*. The leaves of this plant, which is a native of North America, are used as a substitute for tea, and are known by the name of *James's tea*. They were analyzed by M. Bacon, who extracted from them,

1 Water	9 An animal substance
2 Lignin	10 Gum
3 Green resin	11 A potash salt
4 Wax	12 A lime salt
5 Tannin	13 Sulphate of potash
6 Gallic acid	14 Chloride of potassium
7 Bitter principle	15 Phosphate of lime
8 Odorous principle	16 Silica.†

7. *Ilex paraguaiensis*. This tree grows in different parts of South America, especially in Paraguay and the interior of Brazil. In the country it is said to be called *yerva maté*. It rises to the height of an orange tree. The leaves are opposite, shining, oblong, and serrated. The flowers have the botanical characters of those of the *holly*, of which the tree is a species. These leaves are

* Berlin Jahrb. 1798, p. 164. † Jour. de Pharmacie, ix. 558.

almost universally used in South America, under the name of *Paraguay tea.*

The leaves are gathered from plants of only two or three years growth, when the diameter of the stem is about an inch. They are three or four inches long, and have a fine green colour. They are freed from their petioles or leaf stalks, which are hard and woody. When dried they become brittle. The leaves are dried in a kind of oven, heated by the plants previously deprived of their leaves. They are then packed in sacks, and are ready for use.

An infusion of these leaves, in hot water, was used by the native Americans before the conquest of Brazil by the Portuguese. The conquerors learned the use of it, and it has become a fashionable and very common beverage all over South America. It produces a slight degree of intoxication, very agreeable. To the infusion it is customary to add sugar and a little lemon juice, and hot water is poured repeatedly upon the same leaves.

The people of South America ascribe the most admirable properties to this tea. When used in moderation it acts as a stimulant; but when taken in excess it occasions intoxication, and a kind of delirium tremens.*

The dried leaves are yellowish-green, have a very slight herbaceous smell and a bitterish astringent taste. Dr J. B. Trommsdorf is the only chemist who has had an opportunity of examining this tea, and the quantity in his possession was too small for analysis. He detected a yellow colouring matter, two resins, and tannin.† As the infusion becomes muddy when mixed with tincture of nutgalls, it may contain an alkaloid. But the small quantity in his possession did not permit him to search for it.

8. *Rheum palmatum, rhubarb.* The leaves of this plant have been examined by Bouillon La Grange, who found them to contain a considerable quantity of binoxalate of potash and of malic acid.‡

9. *Isatis tinctoria*, or *woad.* The leaves of this plant have been subjected to analysis by Chevreul. The expressed juice, separated by filtration from the *green fecula*, with which it was mixed, deposited, on standing, a blue powder, which possessed the properties of *indigo.* When heated, white flocks separated, consisting no doubt of albumen. When distilled the liquid that came over yielded traces of a *volatile oil*, of *ammonia* and of *sulphur.* When distilled with sulphuric acid, the liquid that came over contained *acetic acid* and *prussic acid.* Evaporated to dryness, and digested in alcohol, it yielded to that liquid a quantity of matter described by him, by the name of *green matter.* It yielded also a yellow-coloured *extractive*, and the following salts: *nitrate of potash, muriate of ammonia, acetate of potash, muriate of potash*, and pure *acetic acid.* The residue thus deprived of the substances soluble in alcohol consisted of *gum, yellow extractive, supermalate of lime, sulphate of*

* Jour. de Pharmacie, xviii. 137.
† Ann. der Pharm. xvii. 89. ‡ Ann. de Chim. lxvii. 91.

lime, and a salt which Chevreul considered as *citrate of lime-and-magnesia*. The green fecula being examined, was found to consist of *green-coloured resin*, *wax*, *indigo*, *gluten*, and *lignin*. The dry matter of the leaves, from which the juice had been expressed, yielded *lignin*, *green resin*, *wax*, *indigo*, *nitre*, a *red-coloured matter*, *malate of lime*, and traces of some other salts.*

The leaves of the *indigofera anil*, examined by the same chemist, yielded the same products with the *isatis*, but the quantity of indigo obtained was much greater.†

The leaves of the *agathophyllum ravensara* were found by Vauquelin to contain an oil similar to the oil of cloves, gum, and carbonate of lime.‡

10. *Menyanthus trifoliata.* This plant was analyzed by Trommsdorf. The fresh plant consists of 75 parts of moisture and 25 of solid matter. The expressed juice, when boiled, lets fall green flocks composed of 75 parts of vegetable albumen, and 25 of green resin. The liquid contains disengaged malic acid, acetate of potash, and a peculiar matter which is precipitated by tannin, but not coagulated by heat, and which is soluble in alcohol. It contains likewise a bitter extractive matter, a brown gum, and a quantity of inulin.§

11. *Centauria benedicta*, or *blessed thistle.* The leaves of this plant, which is a native of Spain and the coasts of the Mediterranean, were formerly used in medicine, and the plant was called *benedicta* or *blessed*, from the supposed medicinal virtues which it possessed. It was considered as a powerful alexipharmic, and capable of curing the plague and other fevers of the most malignant kind. When applied externally to cancers and carious bones it was supposed to heal them. It is needless to observe that these supposed virtues have not been found to hold good by modern practitioners, and that the plant is now seldom or never used in this country as a medicine.

The plant is in greatest perfection when in flower. It should be cut at that time, quickly dried, and preserved in a dry airy place. It has a slight but unpleasant smell, and a very bitter taste.

The leaves of this plant have been analyzed by Morin. The result of his analysis, and the properties of the bitter principle to which it owes its qualities, have been given in a preceding Chapter of this volume.

12. *Guaco.* The leaves of this plant, which is a native of Mexico, were recommended as a specific for the epidemic cholera, when raging some years ago in France. They were subjected to a chemical examination by M. Fauré, an apothecary at Bordeaux, who obtained from them the following substances:—

1 A fatty matter analagous to wax
2 Chlorophylle
3 Guacin

* Ann. de Chim. lxvii. 305. † Ibid. viii. 284.
‡ Ibid. lxxiii. 306. § Ibid. lxxii. 191.

4 Extractive and astringent matter
5 Lignin
6 Some salts of soda, lime, and iron.

The *guacin* has a yellow colour, a bitter taste, and no smell. It is brittle, melts easily when heated to 212°. Very soluble in alcohol and ether, and pretty soluble in boiling water, from which it precipitates as the liquid cools, being little soluble in cold water. Nitric acid dissolves it and gives it a deep yellow colour; sulphuric acid dissolves it less completely, and acquires a deep brown colour; muriatic acid is an imperfect solvent, and does not alter its colour.

It is destitute of alkaline characters. It is considered as the constituent in which the active principle of the guaco resides. But as the effects ascribed to this plant as a specific for cholera have not been sufficiently confirmed, guacin has lost much of the interest that it had at first.*

13. *Eupatorium aya-pana.* The leaves of this syngenesious plant, which is a native of Brazil, but found also in the Isle of France, were much employed in that island as a remedy in the Indian cholera, and also in diseases of the breast and in indigestions. They were subjected to a chemical examination by M. Waflart,† who found them to contain,

1 A fatty matter soluble in ether
2 An essential oil pretty abundant
3 A bitter principle easily separated from the extract by alcohol
4 Starch } a trace of each.
5 Sugar }

14. *Diosma crenata.* This shrub is a native of the Cape of Good Hope. The infusion of its leaves was introduced some years ago into this country, as a remedy for the diseases of the urinary organs, particularly retention of urine. These leaves were subjected to some experiments by M. Cadet de Gassicourt, who extracted from 100 parts of them

1 An essential oil . . .	0·665
2 Gum	21·17
3 Aqueous alcoholic extract . .	5·170
4 Chlorophylle	1·100
5 Resin	2·151
	30·256‡

* Jour. de Pharmacie, xxii. 291. † Ibid. xv. 8. ‡ Ibid. xiii. 106.

CHAPTER X.

OF HERBACEOUS PLANTS.

Under this title I shall notice a few herbaceous plants, which have been examined altogether, leaves, stem, and branches. They are not of much importance, though I think it better to notice them than to pass them over in silence.

1. *Geranium zonale.* This plant, which constitutes a common ornament of gardens, was subjected to some experiments by M. Braconnot.* The plant was pulled in the end of October, pounded in a mortar, and subjected to pressure. The expressed juice filtered rapidly, leaving on the filter green fecula, tannate of lime, chlorophylle, and lignin. The filtered juice was colourless, but assumed a fine blue colour like ink when mixed with persulphate of iron. Braconnot obtained from this juice the following constituents:—

1 A large quantity of bimalate of lime
2 A little bimalate of magnesia
3 Much tartrate of lime
4 Much phosphate of lime and of magnesia
5 Tannin
6 Gallic acid
7 Apotheme
8 Tannate of lime
9 An extractive, insoluble in alcohol, having the savour of roasted meat
10 Malate of potash
11 Chloride of potassium.

2. *Wormwood.* This is the leaves, and likewise the stalks and flower-tops of the *artemisia absynthium*, a plant which grows wild in many parts of Britain. Wormwood has a strong smell, rather disagreeable, and an intensely bitter taste. Its smell is owing to a volatile oil which it contains. It contains, besides, a considerable portion of bitter principle. It was analyzed many years ago by Kunsmuller,† who obtained by water, from 12 parts of wormwood, the following products:—

Resin	0·48
Muriate of potash . . .	0·12
Vegetable acid . . .	0·50
Ditto combined with potash .	2·14
	3·24

The residue, after the action of the water, being burnt, left an ash,

* Ann. de Chim. et de Phys. li. 328. † Ann. de Chim. vi. 35.

which, from 12 ounces of wormwood, contained the following substances:—

Muriate of potash	3 grains
Sulphate of potash	1
Carbonate of lime	59
Alumina	5
Sulphate of lime	5
Silica	4
Oxide of iron	3

Braconnot* subjected this plant to analysis and obtained

Volatile oil	0·15
Green resin	0·50
Bitter resin	0·233
Albumen	1·250
Starch	0·133
Azotized body, having little taste	1·333
Bitter azotized body	3·000
Lignin	10·833
Nitre	0·333
Absynthate of potash	0·917
Water	61·233
	79·915

The *absynthic* acid may be precipitated from the infusion of wormwood by the acetate of lead. It has a very sour taste, is incrystallizable and deliquescent. It does not precipitate solutions of nitrate of lead, mercury, or silver. When poured, drop by drop, into lime or barytes water it occasions a flocky precipitate. With ammonia it forms a salt which crystallizes in four-sided prisms, and which is insoluble in alcohol.

3. *Gratiola officinalis.* This plant was found by Vauquelin to contain, 1. A brown gummy matter, 2. A resinous matter, differing from other resins in being soluble in hot water; but much more soluble in alcohol than in water, and having a very bitter taste. It is in this substance that the purgative quality of the plant resides. 3. A small quantity of animal matter. 4. Common salt in considerable quantity, and another salt which is probably malate of potash. It contained likewise oxalate and phosphate of lime and oxide of iron, probably united to phosphoric acid.†

4. *Conium maculatum*, or *hemlock.* This plant is called *cicuta* in the older pharmacopœias. It is an umbellated plant, very common in Great Britain. Whether the κωνειον of Dioscorides be the same as our conium, cannot be ascertained; nor can any light be thrown upon the poison, by which the Athenians were in the habit of putting their condemned to death. The symptoms of that poison are not only different from those produced by conium, but by every other vegetable poison with which we are acquainted.‡

* Berzelius, Traité de Chimie, vi. 246. † Ann. de Chim. lxxii. 191.

‡ Pliny calls the poison used by the Athenians, *cicuta;* nor am I aware of the word *conium* occurring in any Latin classic.

Hemlock is distinguished from other umbelliferous plants by its large and spotted stem, the dark shining colour of its lower leaves, and their disagreeable smell, if they be bruised when fresh—a smell which has been compared to the urine of a cat. For medicinal use, it should be gathered about the end of June, when the plant is in flower. The footstalks are to be thrown away, and the leaves with their branches carefully dried, and afterwards kept in boxes. Dr Christison has shown, that the common extract of conium of the shops contains little or none of the virtues of the plant.

A chemical analysis of the expressed juice of this plant was made by Schrader, in 1812.* He found a striking similarity between its constituents and those of the expressed juice of the *brassica oleracea*, or *cabbage*. He obtained from 1000 parts of each the following constituents:—

	Conium.	Cabbage.
Extractive .	27·3	23·4
Gummy extract	35·2	28·9
Resin . .	1·5	0·5
Albumen .	3·1	2·9
Green fecula .	8	6·3
	76·1	62·0

The active constituent of this plant is *conicina*, of which an account has been given in a preceding Chapter of this volume.

5. *Chenopodium olidum.* This plant contains uncombined ammonia, to which, in the opinion of MM. Chevalier and Lassaigne, it owes its peculiar smell. The substances extracted from the plant by these chemists, were the following:—

Carbonate of ammonia
Albumen
Ozmazome
An aromatic resin
A bitter matter
Nitrate of potash in considerable quantity
Acetate and phosphate of potash
Tartrate of potash.

100 parts of the plant yielded 5½ of potash †

6. *Asparagus officinalis.* The young shoots of this well-known plant are served upon the table, as an agreeable article of food. From the account which Dioscorides gives of ἀσπαραγος, there is reason for considering it as the same with the asparagus of the moderns. This plant was formerly considered as a diuretic, and was employed in medicine. But it no longer finds a place in any of the British pharmacopœias.

M. Robiquet reduced asparagus to the state of a pulp, and sepa-

* Schweigger's Jour. v. 19. † Annals of Philosophy, xii. 231.

rated its juice by expression. A feculous matter was separated from this juice by filtration. Boiling alcohol dissolved a portion of this fecula, and left matter which possessed the properties of gluten. As the alcohol cooled, a portion of wax precipitated. The alcohol, by evaporation, left a green acrid matter, intermediate in its properties between resin and volatile oil.

The filtered juice had the appearance of whey, and reddened the infusion of litmus. When heated it deposited flakes, which were considered by Robiquet as albumen. When left for a long time to evaporate in the open air, a quantity of asparagin and of saccharine matter, having the appearance of manna, separated in crystals. The juice was inspissated, and treated with alcohol. A portion dissolved; the residue was dissolved in water.

The alcoholic solution, when treated with sulphuric acid, and distilled, yielded vinegar. When this solution was evaporated to dryness and burnt, the ashes consisted of potash, carbonate of lime, and phosphate of potash and of lime. Hence it was probable that the acetic acid was combined with potash and lime.

The watery solution reddened vegetable blues. The infusion of nutgalls throws down a precipitate from this solution. The residue contains a peculiar extractive matter and a colouring matter; and doubtless, also, asparagin and sugar.

Such is the result of Robiquet's very ingenious and interesting analysis of this substance.*

The subsequent facts discovered respecting asparagin, have been stated in a preceding part of this volume, while treating of *aspartic* acid and of *asparagin*.

7. *Cochlearia officinalis*, or *scurvy grass*. This plant, which abounds in the mountainous districts of Scotland, is occasionally employed in medicine as a diuretic, and as a cure for the scurvy produced by living on salt food at sea. Its expressed juice was found by Braconnot† to contain

Sweet matter, thrown down by tannin, and insoluble in cold alcohol . . .	48·33
Organic matter, insoluble in boiling alcohol, precipitated by tannin . . .	32·00
Lime, united to a vegetable acid . .	8·66
Potash, united to the same acid . .	6·66
Muriate and sulphate of potash, and loss	4·33
	100

8. *Mesembryanthemum crystallinum*. The juice of this plant is said to be always colder than the surrounding air. Dr John assures us, that on the 13th of September, when he was engaged in examining it in Berlin, the thermometer in the shade stood at 54°½, but when plunged into the sap of this plant it sunk to 41°. He found this sap composed of the following substances:—

* Ann. de Chim. lv. 152. † Jour. de Phys. lxxxiv. 278.

$\frac{31}{32}$ of its weight of water
Lignin
Extractive
Gum
Resin in minute quantity
Albumen
Green powder
Nitrate of potash in considerable quantity
Common salt
Phosphate of lime
Carbonate of lime.*

9. *Sophora Japanica.* M. Fleurot of Dijon has examined the bark, the wood, the leaves, and the fruit of this plant, and found them to contain the following substances :†—

1 Cathartina
2 An odorous principle
3 Yellow colouring matter
4 Albumen
5 Chlorophylle
6 Starch
7 Gum
8 Mucous sugar
9 Caoutchouc
10 Malate of lime
11 Other salts.

CHAPTER XI.

OF FLOWERS AND POLLEN.

An account of the colouring matters of the different flowers, so far as the subject has been examined, has been given in a preceding part of this volume, while treating of vegetable colouring matters. Our object in this place is to notice a few flowers which have been subjected to a chemical analysis, and to state the facts which have been ascertained respecting the pollen, or fructifying powder, shed by the antheræ of flowers.

1. Flowers of the *carthamus tinctorius*, or *safflower*. In a preceding part of this volume, when treating of red colouring matters, a detailed account was given of safflower, and of the distinguishing colouring matter which it contains, known by the name of *carthamin*. Our object here is merely to state the other constituents which exist in the petals of the carthamus, besides the two colouring matters noticed. The following table exhibits the constituents

* Chemische Untersuchungen, ii. 7. † Jour. de Pharmacie, xix. 510.

of 1000 parts of carthamus, according to the experiments of Dufour:—

Moisture	62
Sand and small particles of the plant	34
Gluten	55
Yellow colouring matter	268
Extractive	42
Resin	3
Wax	9
Red colouring matter	5
Woody fibre	496
Alumina and magnesia	5
Red oxide of iron	2
Sand	12
Loss	7
	1000

If we believe Marchais, a considerable portion of what was considered by Dufour as woody fibre is in reality albumen.

2. Flowers of *arnica montana*. These flowers have been employed in medicine, especially in Germany, where their virtues have been much celebrated. They have a yellow colour, a bitter and sharp taste, and a very weak aromatic smell. When macerated in water, the liquid acquires a brown colour and a bitter taste. It reddens the infusion of litmus, does not form a precipitate with glue, and does not alter the solution of tartar emetic. With sulphate of iron it strikes a deep green, which passes into black on drying. The mineral acids occasion brown precipitates, but the alkaline carbonates produce no change in it.*

When the flowers are macerated in alcohol, the liquid acquires a yellow colour. It reddens vegetable blues, strikes a green with sulphate of iron, and becomes milky when mixed with water. When this tincture is distilled, the alcohol which comes over has a bitter taste, but does not alter vegetable blues; while the liquid which remains in the retort is very acid, precipitates with water, and strikes a green with sulphate of iron. When evaporated to dryness, a bitter acid powder remains, seemingly of a peculiar nature.†

When distilled, the flowers of the arnica yield a yellowish acid liquor, which strikes a black with sulphate of iron. This liquid is covered by a quantity of oil. When these flowers are burnt, the residual ashes contain potash, carbonate of potash, and muriate and sulphate of potash.‡

These flowers have been subjected to a chemical examination by MM. Chevallier and Lassaigne, who extracted from them the following substances:—

* Bouillon La Grange, Ann. de Chim. lv. 38.
† Ibid. lv. 39. ‡ Ibid.

A resin having the odour of arnica
A bitter nauseous substance resembling the emetic substance from the cytisus laburnum
Gallic acid
A yellow colouring matter
Albumen
Gum
Muriate and phosphate of potash
Traces of sulphates
Carbonate of lime
Silica.*

3. *Artemisia santonica*, or *Tartarium*, *southernwood*. The tops of the ripe flowers of this plant, and formerly the seeds, were used as anthelmintics, under the name of *santonicum*. The plant is said to be a native of Tartary and Persia. What is used in medicine comes partly from Aleppo and partly from India. It consists of small linear grains of a greenish yellow colour, mixed with about $\frac{1}{5}$ of the weight of small tubercles considered as the summits of the ripe flower. It is called by the French *barbotine*, *sementine*, or *cinæ semen*, *semencontra*, that is *contra vermes*. According to the analysis of Trommsdorff† it contains,

Volatile oil	0·8
Hard resin	11·0
Bitter extract with malate of lime	21·0
Gum and extract insoluble in alcohol	36·0
Matter soluble in potash, very similar to gummy extract . .	20·0
Fibrin	12
	100·8

The matter subjected to this analysis, had been dried at a pretty high temperature, by which it lost 10 per cent. of its weight.

The active principle in the medicine seems to reside in the volatile oil, which may be obtained by distilling the santonicum with water. It has a pale yellow colour, a strong aromatic odour, and an acrid bitter taste, and is very volatile. It requires 1000 times its weight of water to dissolve it, but it dissolves with facility in alcohol and ether.

Since the analysis of Trommsdorff, *santonicum* has been examined by Kohlar and Alms,‡ who discovered about the same time a crystalline matter which it contains, to which the name of *santonin* has been given. It was afterwards investigated more closely by Trommsdorff junior, who showed that it possessed acid properties. An account of it has been already given in a preceding Chapter of this volume.

4. *Tilia Europeæ*, or *lime tree*. The flowers of this tree contain, according to Pfaff,§ an odoriferous substance which may be distilled over along with water, but which cannot be procured under the form

* Annals of Philosophy, xvi. 90.
† N. Tr. iii. 1, 309.
‡ Jour. de Pharm. xvii. 115.
§ Materia Med. iv. 92.

of a volatile oil. They contain also tannin, fermentible sugar, much gum and lignin.

Brossat found, that when 100 lbs. of lime tree flowers were distilled with water till 80 lbs. had passed over, the liquid thus obtained was muddy. When it was distilled anew, with 100 lbs. of the flowers till 40 lbs. of liquid passed over, a muddy liquid was obtained having an agreeable smell, on the surface of which some golden yellow drops swam. When preserved for five months in a cellar, it became mucilaginous like a decoction of lintseed, without losing its agreeable smell. When taken into the stomach, it produced intoxication.

According to Roux,* alcohol extracts from the flowers of the lime tree chlorophylle and a yellow extractive matter. During the evaporation, the chlorophylle separates and leaves the yellow matter in the state of a brownish yellow solid which dissolves in water, communicating to it a yellow colour. Cold water extracts from the flowers, previously treated with alcohol, an additional quantity of the yellow matter, and a substance insoluble in alcohol, and precipitated by it in white flocks, which become brown when exposed to the air. The aqueous solution of this substance is precipitated olive by the salts of copper, greyish black by the proto-salts of iron, and yellow by corrosive sublimate, showing an essential difference from gum.

If, after exhausting the flowers of the lime tree by means of alcohol and water, we boil them for some hours in water, we obtain a reddish-brown decoction. If we filter this decoction, concentrate it by evaporation, and then pour into it alcohol, a great quantity of red colouring matter precipitates. When dry it is brownish red, weakly astringent, and is insoluble in alcohol and ether, but soluble in water, and is capable of precipitating the metallic salts. Acids destroy its colour, but alkalies produce little alteration in it. Berzelius considers it as a compound of gum and the apotheme of tannin.

5. *Calendula officinalis*, or *marygold*. The flowers of this well known plant, so common in our gardens, were formerly used in medicine; but they have been struck out of all the British pharmacopœias. They contain, according to the analysis of Geiger,†

Greenish yellow soft resin .	3·44
Bitter extractive . . .	19·13
Gum	1·50
Starch	1·25
Calendulin	3·50
Albumen	0·62
Malic acid with bitter extractive	6·84
Malate of potash . . .	5·45
Malate of lime . . .	1·47
Chloride of potassium . .	0·66
Lignin	62·50
	106·36

* Jour. de Pharm. xi. 507. † Diss. de Calendula Officinali. Heidelberg, 1819.

The *calendulin* of Geiger appears to be a species of vegetable mucilage. Its properties, and the method of obtaining it, have been described in a preceding Chapter of this volume.

The antheræ of most vegetables, at the time that the flower is in perfection, are covered with a considerable quantity of a powdery matter, usually of a yellow colour, which, falling upon the pistils, is supposed to impregnate them. This matter is known by the name of *pollen*. In some plants, especially those in which the male and female flowers are separate, the quantity of it is so great, that it may easily be collected.

The first person who examined this powder was Dr Lewis; but in his time chemistry had not made sufficient progress to enable him to make a complete analysis. He found that alcohol in which it is macerated, acquires a bright yellow colour, and that water takes a duller yellow, while the undissolved portion, is of a yellowish-white colour. The colour of these infusions is heightened by alkalies, and turned *red* by acids. When alkalies are dropt into the reddened solution, a deep yellow colour is restored.*

Fourcroy and Vauquelin have published a detailed analysis of the pollen of the *phœnix dactilifera*, or date tree, which may be considered as furnishing a pretty correct view of the properties of this class of vegetable substances. At least it is probable that the pollen of different vegetables does not differ nearly so much from each other as the other parts of plants.

The pollen of this tree is so abundant, that at the season of fructification, it surrounds the plants like thick dust. The specimen examined was brought from Egypt by Delisle. Its colour was sulphur-yellow, its taste was sourish and unpleasant, it reddened the infusion of litmus, and communicated to water a yellow colour, and a sensible degree of acidity. The watery infusion was precipitated by lime water and ammonia, by alcohol, and by some metallic salts.

When pollen was washed in cold water, that liquid acquired a reddish-brown colour, a sourish taste and smell, not unlike that of beer. When evaporated, the liquid left a reddish-brown matter, which had the consistence and odour of molasses; its taste was acid, but disagreeable. Cold alcohol produced no effect upon this matter, but by the assistance of heat it dissolved a portion of it, and assumed a dark colour. The residue had more consistence and was less coloured. It dissolved with facility in water, allowing at the same time a greyish bulky matter to separate. Thus the matter taken up by the watery infusion from pollen has been divided into three portions.

The alcoholic solution being concentrated by evaporation to the consistence of an extract, had a red colour, the odour of baked apples, and a taste strongly acid, but disagreeable. It presented all the characters of malic acid. The grey matter, which refused to dissolve in water, possessed the properties of phosphate of lime.

The aqueous solution was ascertained to consist chiefly of phos-

* Neumann's Chem. p. 231.

phate of magnesia, malic acid, and an animal matter, which formed a copious precipitate with the infusion of nutgalls.

The pollen, thus deprived of its soluble matter, being exposed on filtering paper to the open air for a week, instead of drying assumed the form of a paste, and ran rapidly to putrefaction, emitting an odour similar to that of old cheese. When dried, this matter became semitransparent, and of a consistence resembling that of glue. Before being dried it mixed readily with water, and exhibited the characters of soap. The fixed alkalies showed the presence of ammonia in it. When distilled there came over a watery liquid, which gradually became coloured as the distillation advanced: some time after there came over a red coloured oil and carbonate of ammonia, partly in crystals, and partly in solution. The liquid also contained a portion of the oil in the state of a soap. The charcoal left was voluminous, and difficult of incineration. When burnt it left a considerable portion of phosphate of lime. This substance is the pollenin of John.

The pollen is partly soluble in muriatic acid. The nitric acid reduces it to a paste, azotic gas is disengaged, and afterwards, on the application of heat, nitrous gas and carbonic acid. A yellowish oil separated and swam upon the surface, and alkalies separated earthy phosphates and oxalates. When the liquid was evaporated to dryness, it left a yellowish-red matter, extremely bitter, tenacious and adhesive, and perfectly soluble in water. This matter, from the description of it, must have been a species of artificial tannin. Thus it appears, that by the action of nitric acid, the portion of the pollen which is insoluble in water is converted into oil and artificial tannin. The oily matter became solid on cooling, and possessed almost exactly the properties of tallow treated with nitric acid.

Strong alkaline leys dissolve the pollen, and assume with it the properties of soap, while ammonia is disengaged.

When the pollen, mixed with water, is set aside to ferment, it disengages the odour of new cheese, and assumes the form of a tenacious mass. Its taste is extremely sharp; it contains abundance of ammonia, partly united to oil, and partly to malic acid. From all these phenomena, there is reason to believe that the insoluble part of the pollen approaches vegetable gluten in its properties; or rather, that it is intermediate between gluten and albumen.

Such are the properties and constituents of the pollen of the date tree, as far as they have been ascertained by Fourcroy and Vauquelin.*

Professor Link has examined the pollen of the hazel nut. It differs a good deal from that of the date tree just described. He found in it tannin in great abundance, a resin, a good deal of gluten, and a little fibrin.† The pollen of the tulip, which has been carefully analyzed by Grotthus, is also very different from that of the date tree. He could neither detect in it phosphorus nor pollenin. From 26 grains of it he extracted

* Ann de Mus. d'Hist. Nat. i. 417. † Ann. de Chim. lxii. 292.

Vegetable albumen	20·25
Malate of lime with trace of malate of magnesia	3·50
Malic acid	1·00
Malate of ammonia, Colouring matter, Saltpetre?	1·25
	26·00*

3. The pollen of the *pinus sylvestris* or *Scotch fir*, according to the analysis of John, is composed of

Cerin	2·00
Oil	trace
Brownish-yellow resin	3·75
Malates of potash, lime, and magnesia, with some gum	5·00
Sugar, with a trace of extractive	5·00
Albumen	4·00
Pollenin	77·25
Sulphate, Muriate, Phosphate of potash; Phosphate of lime; Oxide of iron	3·00
Malate of ammonia	trace
Sulphur?	trace
	100·00

4. The constituents of the pollen of the *pinus abies* he found as follows:—

Cerin	2·25
Oil	trace
Brownish-yellow resin	4·00
Malates of potash, lime, and magnesia, with some gum	6·00
Sugar	4·50
Extractive	trace
Albumen	4·00
Pollenin	75·25
Sulphur?	trace
Malate of ammonia, Sulphate, Muriate, Phosphate of potash; Phosphate of lime; Oxide of iron	3·00
	100·00

5. The pollen of *juglans regia*, *cannabis sativa*, *zey mays*, and of tulips, was likewise examined by Dr John, and found to contain nearly the same ingredients, though not in quite the same proportions.†

* Schweigger's Jour. xi. 281. † Chemische Untersuchungen, iv. 27.

6. The pollen of the *tulipa suaveolens*, or common tulip, was examined by John.* He found in it the following constituents:—

1 Yellow coloured pollenin
2 Much uncrystallizable sugar
3 A little cerin, tinged blue
4 A violet blue pigment soluble in water and alcohol
5 Volatile matter
6 Supermalates of potash, lime, and magnesia
7 Traces of other salts with the same bases
8 Albumen.

7. *Typha latifolia.* M. Braconnot examined in 1829, the pollen of the *typha latifolia*, which it is well known is abundant, and is sometimes mixed with *lycopodium*, though it does not burn quite so rapidly. He obtained:—†

1 Water		47
2 Pollenin	}	25·96
3 Yellow colouring mattter	}	
4 Sugar	}	18·32
5 Matter slightly azotized	}	
6 Gum	}	
7 Fat formed of stearin and olein		3·60
8 Starch		2·08
9 Phosphate of magnesia and lime		1·28
10 Phosphate of potash‡		1·28
11 Malate of potash		0·40
12 Silica		0·40
13 Oxide of iron		trace
		100·32

The properties of the pollenin of the typha, were different from those of the *phenix dactylifera*. The grains of typha pollen contained starch, which seemed to occupy the interior portion of each particle, and cannot be removed by boiling water nor acetic acid. But boiling dilute solution of tartaric acid dissolves it, and so does muriatic acid. The portion of the pollen insoluble in water, deprived by caustic potash of the starch, the fatty matter, and a portion of the colouring principle may be considered as the pollenin.

It is azotized, but much less so than albumen; insoluble in caustic alkalies and in boiling muriatic acid, but soluble in concentrated sulphuric acid, from which it is precipitated by water. It dissolves also with difficulty in concentrated boiling acetic acid, and water throws it down in white curdy flocks. When in this state of division it is soluble in ammonia and in caustic potash, from which it may be separated by acids in the state of a white coagulum. If we boil the potash solution of this pollenin its nature is altered, for it cannot be thrown down by acids; but it is precipitated from the saturated solution by alcohol and by the infusion of nutgalls.

* Schweigger's Journal, xii. 244. † Ann. de Chim. et de Phys. xlii. 91.
‡ Containing some muriate and a trace of sulphate.

When dried it has the translucency of horn. When distilled it swells up and gives an oily and slightly ammoniacal liquid, but no trace of carbonate of ammonia appears. When treated with nitric acid it furnishes carbazotic acid but no trace of oxalic acid.

8. *Papaver rheas.* The petals of this plant have been subjected to a chemical analysis by M. Riffard,* who extracted from them

Yellow fatty matter
Red colouring matter
Gum
Lignin.

The fatty matter was extracted by ether; the colouring matter by alcohol. It was a dark-red matter, which deliquesced in the atmosphere, and probably was far from pure.

CHAPTER XII.

OF SEEDS AND FRUITS.

The seeds of vegetables, constituting one of the most important articles of food, and being the materials from which a variety of useful substances are procured, have been more subjected to chemical experiments than any of the other parts of plants.

They all contain a considerable portion of starch, though this matter differs somewhat in its properties in different seeds. Gluten is likewise a common ingredient, but extremely various both in its quantity and in its appearance. Some seeds contain a saccharine matter, as those of the *lycopodium;* but the quantity is always small, and its properties are hardly ever the same as those of true sugar. Fixed oil is also a common ingredient. In the seeds of the grasses, the proportion of it, if any can be detected, is always small: the same remark applies to the seeds of the papilionaceous plants; but the seeds of the cruciform plants abound in a limpid and nearly insipid oil. In some seeds a volatile oil is present, but this is not common. Some possess a peculiar colouring matter; some possess a portion of bitter principle, as the seeds of the common broom and of the coffee plant.

Saussure, junior, has shown that wheat, and probably every other kind of corn, yields a quantity of phosphorus, if it be charred in a moderate heat, and the charcoal be afterwards violently heated in a porcelain retort. He has shown that the phosphorus, in this case, is owing to the decomposition of phosphate of potash, which exists in these seeds, and which is decomposed by the charcoal at a very high temperature. He found that phosphate of soda, and even phosphate of lime, may be decomposed in the same way.† Thus

* Jour. de Pharmacie, xii. 412. † Ann. de Chim. lxv. 189.

the observations of Margraff, and some of the earlier chemists, respecting the phosphorus which may be obtained from the seeds of plants have been verified.

Gay-Lussac has observed that seeds, almost without exception, contain azote. For when distilled they yield ammonia; or at least a product from which ammonia may be evolved by means of quicklime.*

It is scarcely necessary to remark, that only a comparatively small number of seeds and fruits have been hitherto subjected to chemical analysis.

1. *Wheat*, the *triticum hybernum*, *æstivum*, and other species, has been cultivated from time immemorial in Europe and the northern parts of Africa, and the seeds of it employed as one of the most important articles of food. Indeed wheat flour is the only substance known from which good loaf bread can be made. The seeds, when ripe, are ground to a fine powder, and by passing this powder through cloth sieves, of various degrees of fineness, it is separated into distinct portions. The fine flour constitutes the greatest portion; and the *bran*, which consists of the outer coat of the seed, and which is the coarsest of all, constitutes the next greatest portion.

The common wheat of this country, which is the *triticum hybernum*, was analyzed by Vauquelin,† who obtained the following constituents from different varieties of it.

	French wheat.	Odessa hard wheat.	Odessa soft wheat.	Ditto.	Ditto.	Flour of Paris bakers.	Ditto of good quality, used in public establishments.	Ditto inferior kind.
Starch . .	71·49	56·5	62·00	70·84	72·00	72·8	71·2	67·78
Gluten . .	10·96	14·55	12·00	12·10	7·30	10·2	10·3	9·02
Sugar . .	4·72	8·48	7·56	4·90	5·42	4·2	4·8	4·80
Gum . .	3·32	4·90	5·80	4·60	3·30	2·8	3·6	4·60
Bran . .	——	2·30	1·20	——	——	——	——	2·00
Water . .	10	12·00	10	8·00	12	10·0	8	12·00
	100·49	98·73	98·56	100·44	100·02	100·0	97·9	100·20

It appears from the preceding analyses that the Odessa wheat contains a much greater quantity of sugar than French wheat. The gluten of the preceding table is, in fact, a mixture of gluten and albumen. The gum differs from common gum. It has a brown colour and contains azote. When treated with nitric acid it does not form mucic acid, but oxalic acid and the bitter principle of Welter.

M. Zenneck, in 1823, analyzed the seeds of the *triticum dicoccon*, employed in Germany as food for birds.‡ From 100 parts of these seeds, well dried, he obtained,

* Jour. de Pharmacie, xx. 29. † Ibid. viii. 353.
‡ Schweigger's Jarhbuch, ix. 323.

Gluten	13·00
Husk	19·88
Starch	58·81
Bitter matter, soluble in ether .	2·97
Sweet extractive matter* .	2·37
Mucilage and albumen . .	2·97
	100·00

The finest flour from *triticum spelta*, was analyzed by Vogel,† in 1816, and found by him to contain

Starch	74
Gluten	22
Sugar	5·5
Albumen	0·5
	102

The flour from the *triticum monococcum* was likewise analyzed by Zenneck.‡ He obtained

Resin, extract, sugar, and gum	11·35
Starch	64·84
Lignin	7·48
Gluten	14·96
Albumen	1·37
	100·00

2. Rye is the seed of the *secale cereale*, a plant cultivated in the northern parts of Europe, in considerable quantity, as an article of food. Bread made of it is much denser than wheaten bread, and has a brownish colour, and a peculiar sweetish taste, which to most persons is rather agreeable. We are indebted to Einhof for an elaborate analysis of rye-meal. He published the result of his experiments in the summer of 1805.§

A determinate portion of rye-meal was formed into a paste, and washed in pure water till that liquid ceased to acquire any colour, or take up any thing. The liquid, after filtration, had a yellowish colour, an insipid taste, and a smell like that of new whey. It slightly reddened litmus paper, and was rendered muddy by carbonate of potash, sulphate of silver, and infusion of galls. When raised to the boiling temperature, it became muddy, and a number of white flakes separated. These, when collected and edulcorated, had the appearance of curd. They dissolved in alkaline leys, were insoluble in alcohol, and possessed the properties of *vegetable albumen*. When the liquid was concentrated by evaporation, it deposited a small additional portion of albumen. This being separated, the liquid was evaporated to the consistence of honey, and digested in alcohol repeatedly till nothing more was taken up. The residue was greyish-white and insipid: water dissolved it slowly, and the

* Soluble in water and alcohol.
† Schweigger's Journ. xviii. 381.
‡ Ibid. xliii. 487.
§ Gehlen's Jour. v. 131.

solution, being evaporated, deposited more flakes of albumen. The residue had the appearance of a solution of gum arabic, and when evaporated to dryness, left behind it a portion of gummy matter.

The alcoholic solution became muddy when mixed with water. The alcohol being drawn off by distillation, there remained in the retort an aqueous solution, of a wine-yellow colour with large brownish flakes swimming in it. These flakes, when collected, were found to possess the properties of gluten. They formed a glutinous mass with cold water, the bulk of which contracted when the water was made to boil. Boiling alcohol dissolved it; but ether took up only the colouring matter. Alkalies dissolved it, and acids threw it down again from its solution.

The watery solution, thus freed from the gluten, being evaporated, left an extract of a wine-yellow colour. By repeated digestions in alcohol, dilutions with water, and evaporations, it was freed from a portion of gluten, which still adhered to it. Its taste was then sweet, but harsh; its colour wine-yellow; and it was soluble in water, alcohol, and ether. It was considered as the saccharine matter of rye.

The rye-meal, thus freed from the matters soluble in water, was mixed with a great quantity of water, and by repeatedly agitating the liquid, and decanting it off after standing some time, it was separated into two portions; namely, a greyish-coloured substance, which, being lightest, did not so soon subside, and a white powder which possessed the properties of starch. The grey-coloured substance, by repeated digestions in alcohol and water, was separated into three portions; namely, gluten, starch, and the coats of the rye-seeds. Such are the constituents of rye-meal, according to Einhof. The following are the proportions of these different substances, detected by this chemist, in the best rye-seeds and rye-meal. 3840 parts of good rye-seeds were composed of

Husk	930
Moisture	390
Pure meal	2520
	3840

100 parts of good rye-meal contained

Albumen	3·27
Gluten, not dried	9·48
Mucilage	11·09
Starch	61·09
Saccharine matter	3·27
Husk	6·38
Loss	5·42
	100·00

But the proportion of these substances must vary extremely according to the soil, the climate, and the age of the rye. The gluten of rye differs in several particulars from that of wheat. It is less

tenacious and more soluble. When it was allowed to ferment, Einhof perceived a strong smell of nitric acid, which is peculiar to this species of gluten. The starch of rye bears a striking resemblance to that of wheat. Like this last, it does not form a colourless solution with boiling water, and always precipitates at last, when the solution is left a sufficient time at rest.

Einhof did not examine the ashes of rye; but from the experiments of Schrader, we know that the same quantity, analyzed by Einhof, namely, 3840, yielded the following fixed substances.*

Silica	3·90
Carbonate of lime . . .	3·35
Carbonate of magnesia . .	3·55
Alumina	0·35
Oxide of manganese . . .	0·80
Oxide of iron	0·22
	12·17

It is well known that rye is liable to a disease which alters the appearance of the grain, and gives it new properties. In this state it is distinguished in France by the name of *seigle ergoté*, and we give to the seeds of rye altered by this disease, the name of *ergot of rye*, or in Latin *secale cornutum*. The ergot is a kind of spur which issues from the grain of rye. It is elongated and curved, marked with three blunt angles and longitudinal lines. Its colour is violet of different shades. Internally it has a dirty-white colour. When collected in quantities, it emits, while fresh, a disagreeable smell. Its taste is slightly biting and nauseous. Its length is about an inch or an inch and a half, and its thickness about a quarter of an inch. According to Decandolle, it is a species of fungus to which he has given the name of *sclerotium clavis*. Others consider it as a morbid alteration of the ovarium of the rye, caused by the puncture of an insect of the genus *musca*, and which deposits a blackish liquid.

When taken into the stomach in any quantity, it produces tetanus, gangrene, and death. In small doses it stimulates the uterus, and is very useful in cases of difficult parturition.

According to the analysis of Vauquelin,† it contains a soft yellowish red *resin*, having an acrid taste, and leaving in the mouth an impression similar to that of fish oil; a sweet soft *oil*, which may be obtained either by expression or by boiling the ergot in water after it has been exhausted by alcohol, the oil separates and swims on the surface of the decoction; a violet *colouring matter*, soluble in water, but insoluble in alcohol, which gives a reddish-yellow colour to silk or wool impregnated with alumina; a great quantity of an *azotized substance*, which is insoluble in alcohol, soluble in water, and precipitated by infusion of nutgalls, which putrefies readily, giving out the smell of putrid fish. Ergot contains neither starch nor sugar, but an uncombined acid, which may be the phosphoric.

* Gehlen's Jour. iii. 525. † Ann. de Chim. et de Phys. iii. 337.

Pettenkofer* found that when ergot was treated with weak alcohol it furnishes a brownish-red tincture, which deposits, when the greater part of the alcohol is distilled off, 18·75 per cent. of a soft green wax, which melts at 212°, and when burnt leaves a charcoal containing phosphoric acid. The liquid freed from the wax gives a brown, transparent, bitter, and acidulous extract, which continues soft though heated to 176°, and absorbs moisture rapidly in the air. Pettenkofer, after some days, observed in this extract some cubic crystals which he considered to be phosphate of morphina, but this conjecture has not been proved.

3. *Oats* are the seeds of the *avena sativa*, a plant cultivated in considerable quantities as an article of food. The husk is uncommonly thick, and constitutes a considerable portion of the corn. The proportion of starch is likewise considerable, though it is difficult to free it from another substance with which it is united.

Vogel found that 100 parts of oats consisted of

Meal	66
Husk	34
	100

The dried meal yielded

Fat yellowish-green oil . .	2
Bitter extract and sugar . .	8·25
Gum	2·5
A grey substance like albumen .	4·3
Starch	59·0
Moisture and loss . . .	23·95
	100·00

4. *Barley* is the seed of the *hordeum vulgare*, a plant too well known to require any description. Great crops of it are reared annually, partly as an article of food, and partly as a material from which malt liquors and ardent spirits are drawn. This species of corn has been examined with considerable attention by chemists, partly in order to form correct conceptions, if possible, of the nature of the process of fermentation, and partly to ascertain the constituents of barley. Fourcroy and Vauquelin published several ingenious remarks and experiments on it in 1806,† and Einhof published a still more elaborate analysis about the commencement of the same year; having examined this grain in different stages of its growth, and after it was fully ripe.‡

When unripe barley-corns are triturated with water, the liquid acquires a milky colour. If this process be continued, adding fresh portions of water as long as the liquid passes off muddy, there remains only a green husky matter. When this matter is macerated a sufficient time in cold water, it acquires a greenish-grey colour, and when dry has the appearance of vegetable fibre. The water in

* Repert. iii. 65.

† Ann. de Mus. d'Hist. Nat. No. xxxvii. p. 5.

‡ Gehlen's Jour. vi. 62.

which it was macerated, when boiled, deposits a few flakes of albumen, and when evaporated to dryness leaves a small portion of extractive.

The water with which the barley was triturated is at first milky, and gradually deposits a white powder; yet it does not become transparent, though allowed to stand a considerable time. When filtered, it passes through transparent, while a slimy substance of a greenish-grey colour remains upon the filter. This substance possesses the properties of gluten. When the solution, now transparent and of a yellowish colour, is boiled, it deposits flakes of albumen. It reddens litmus paper, and is strongly precipitated by lime-water, nitrate of lead, and sulphate of iron, indicating the presence of phosphoric salts.

The liquid being evaporated to the consistence of a syrup, and the residue treated with alcohol, the solution diluted with water, and the alcohol distilled off, to separate some gluten which still remained, a syrupy matter was obtained, having a sweet taste, which was considered as the saccharine matter of the barley. A portion refused to dissolve in alcohol. This portion was considered as extractive.

The white powder which precipitated from the water in which the barley had been originally triturated possessed the properties of starch.

Such are the constituents of unripe barley, according to the experiments of Einhof. The following are the proportions of each which he obtained from 2880 parts of unripe barley:—*

Green husk, &c. . . .	478
Albumen, with phosphate of lime	13
Gluten	51
Saccharine matter . .	160
Extractive	76
Starch	420
Volatile matter . . .	1500
Loss	182
	2880

When ripe barley is steeped in water a sufficient time, and then cautiously kneaded between the fingers in a cloth, every part of the grain is washed away except the husk, which by this process may be dried and weighed.

When barley meal, previously made into a paste, is treated in the same way, a brownish residuum remains, consisting chiefly of the husk, though it contains also portions of starch and gluten which cannot well be separated. The water in which the meal has been washed gradually deposits a white powder, but does not become transparent though left at rest. It runs very soon into acidity. Indeed, if we believe Fourcroy and Vauquelin, barley often con-

* Gehlen's Jour. vi. 83.

tains an acid; the water in which it has been macerated reddening the infusion of litmus: this acid is the acetic. The colour of this water is reddish-brown. It holds in solution a considerable portion of matter, which, according to Fourcroy and Vauquelin, consists chiefly of gluten, but which Einhof found to be of a more complicated nature, consisting of albumen, or rather gluten, mucilage, and saccharine matter. It contains in solution likewise a notable portion of phosphate of lime.

When barley meal is macerated a sufficient time in alcohol, that liquid acquires a yellow colour, and becomes muddy and more odorous, and by evaporation leaves an oily matter of a yellow colour and an acrid taste, having the consistence of butter. This oil burns like a fat oil, and forms soap with alkalies. It is but imperfectly soluble in alcohol.* This oil escaped the observation of Einhof. I obtained it by a process similar to that afterwards described by Fourcroy and Vauquelin; but its colour was asparagus green, and it did not burn with the same readiness as an oil. It has very much the appearance of olive oil coagulated, but its consistence is less, and its colour is darker. To this oil the peculiar flavour of spirits from raw grain is ascribed at present. If this opinion be well founded, the oil must be dissipated or destroyed by the process of malting.

The following are the proportions of the constituents obtained by Einhof from 3840 parts of barley-corns:—

Volatile matter	430
Husk	720
Meal	2690
	3840

From the same quantity of barley-meal he obtained

Volatile matter	360
Albumen	44
Saccharine matter . . .	200
Mucilage	176
Phosphate of lime, with some albumen	9
Gluten	135
Husk, with some gluten and starch	260
Starch, not quite free from gluten	2580
Loss	76
	3840

Besides these substances, Fourcroy and Vauquelin ascertained the presence of phosphates of lime and magnesia, and of silica and iron; and I found in it phosphate of potash and nitrate of soda. The presence of phosphate of potash was ascertained likewise by Saussure, junior.

5. *Rice*, the seeds of the *orysa sativa*, have been analyzed by Braconnot. He found in this grain the following constituents:—

* Fourcroy and Vauquelin, Ann. de Mus. d'Hist. Nat. No. xxxvii. 8.

	Carolina Rice.	Piedmont Rice.
Water	5·00	7·00
Starch	85·07	83·80
Parenchyma	4·80	4·80
Gluten	3·60	3·60
Uncrystallizable sugar	0·29	0·05
Gummy matter approaching starch	0·71	0·10
Oil	0·13	0·25
Phosphate of lime	0·13	0·40
	99·73	100·00

Besides traces of muriate of potash, phosphate of potash, acetic acid, sulphur and lime and potash united to a vegetable alkali.*

Vauquelin was unable to detect any saccharine matter in rice. He found in it a little phosphate of lime and gum.†

6. *Mais* is the seeds of the *zea mais*, or Indian corn, a native of America, but now cultivated in Italy and other southern countries of Europe. It was cultivated and much used in Peru, before the conquest of that country by the Spaniards. They even knew the method of fermenting it, and of producing from it an intoxicating liquid, to which they gave the name of *chicea*.

Mais was first analyzed by Professor Gorham.‡ He obtained

	Fresh.	Dried.
Water	9	
Starch	77	84·599
Zein	3	3·296
Albumen	2·5	2·747
Gum	1·75	1·922
Sugar	1·45	1·593
	94·7	94·157

M. Bizio§ made a subsequent analysis of it in 1823, and obtained

Starch	80·920
Zein	5·758
Extractive	1·092
Zimome	0·945
Gum	2·283
Sugar	0·895
Fat oil	0·323
Hordein	7·710
Salts, acetic acid and loss	0·074
	100·000

The extractive matter possessed peculiar properties. While warm, it could be drawn into threads like turpentine, and could be kneaded between the fingers without adhering to them. After

* Ann. de Chim. et de Phys. iv. 370.
† Annals of Philosophy, xii. 151.
‡ Journal of Science, xi. 205.
§ Schweigger's Jour. xxxvii. 377.

cooling, it became hard and brittle, and could be separated into thin translucent cinnamon-coloured pieces. It had a sweetish-bitter taste and the smell of honey. It dissolved readily in alcohol and water, when freed from foreign matter by repeated solutions in alcohol. It was insoluble in ether, but dissolved readily in acetic acid and muriatic acid. It deliquesces when exposed to the air. When boiled with metallic salts, it throws down a precipitate.

Gorham gave the name of *zein* to the gluten which mais contains. The mode of procuring it, and its properties, have been given in a preceding Chapter of this volume.

M. Pallas has shown, that the stem of mais, before flowering, contains no sugar; at the time of flowering, it contains a trace of crystallizable sugar. Twenty or twenty-five days after flowering, it contains 1 per cent. of crystallizable sugar. When the grain is ripe and only requires to be dried, the stem, being still green, contains 2 per cent of sugar and 4 per cent. of molasses, having an exceedingly agreeable taste.*

7. *Peas.* The seeds of the *pisum sativum* constitute a very common and nutritive article of food. They have been examined in different states by Einhof,† who has devoted his chief attention to this peculiar branch of chemical investigation.

By treating the green plant nearly in a similar manner with barley, he obtained from 3840 parts the following constituents:—

Volatile matter	3000
Starch	53
Vegetable fibre	400
Gluten‡	70
Albumen	35
Phosphate of lime	4
Saccharine matter	176
Extractive	25
Loss	77
	3840

The green pod or husk of the tree, by a similar treatment, yielded, from 3840 parts,§

Volatile matter	3120
Vegetable fibre	344
Starch	90
Green gluten	22
Albumen	17½
Phosphate of lime	3½
Saccharine syrup	182
Loss	61
	3840

* Jour. de Pharmacie, xxii. 386. † Gehlen's Jour. vi. 115.

‡ In the same state as that from the leaves of plants, and mixed with the green colouring matter. § Gehlen's Jour. vi. 119.

The peas themselves, when very young, are often filled with a sweet juice, which may be obtained by a slight pressure. Einhof examined this liquid. It has a greenish-yellow colour and a very sweet taste. When exposed to the air, thin cuticles formed on its surface, and white flakes precipitated. It gradually underwent a kind of fermentation and became sour. From 1440 parts of this juice, Einhof obtained, by analysis,*

Albumen	10
Extractive	18
Saccharine syrup	155

This syrup had much the taste of raw sugar, but could not be made to crystallize.

From ripe peas, by macerating them in water, and employing a mode of analysis similar to that used for ascertaining the constituents of barley, Einhof obtained the following products. The quantity employed was 3840 parts.†

Volatile matter	540
Starchy fibrous matter, with the coats of the peas	840
Starch	1265
Animo-vegetable matter	559
Albumen	66
Saccharine matter	81
Mucilage	249
Earthy phosphates	11
Loss	229
	3840

The second of these constituents, entitled *starchy fibrous matter*, was what remained after the peas, reduced to a pulp with water in a mortar, had been washed with water till they ceased to discolour it, or to give out any soluble matter to it. This residue was in part composed of the coats of the peas, and partly of a white fibrous matter without taste or smell. When dried, it became yellowish, and was easily reduced to powder; and the powder formed a paste with water, and dissolved like starch in hot water. It then bore a certain resemblance to starch, and agreed in its properties with the fibrous matter of potatoes.‡

The fourth of the preceding constituents, entitled *animo-vegetable matter*, was obtained in this manner: the milky water in which the peas had been macerated, after depositing the starch, still continued muddy, but neither deposited any thing, nor would pass through the filter; but when diluted with its own bulk of water, it gradually deposited a powder, the whole of which, being collected on a filter, constituted the substance to which Einhof gave the name of *animo-vegetable matter*. It approaches most nearly to gluten; but as it differs in several particulars both from gluten and from all other vegetable constituents, we must consider it as a peculiar principle.

* Gehlen's Jour. vi. 120. † Ibid. 13. ‡ Ibid. 123.

Its colour was at first white; it had no taste nor smell, but reddened vegetable blues, even after having been repeatedly washed in cold water. It was glutinous and adhesive, and could be kneaded into a paste. It was insoluble in water, both cold and hot; but when mixed with that liquid it soon putrefied; and on being treated with lime, gave out the smell of ammonia. In the pure alkaline leys it dissolves readily, and forms a kind of soap; but the carbonates require heat to produce the solution. Sulphuric acid dissolves it; the solution is light-brown, and when diluted with water, lets fall a white thread-like substance. It dissolves also in muriatic acid and chlorine, and in acetic acid. Nitric acid gives it a lemon-yellow colour. It dissolves also in alcohol, and the solution becomes milky when mixed with water. The tincture of galls throws down a copious white precipitate. Ether and volatile oils have no action on it. When dried, it assumes a light-brown colour and the semi-transparency of glue, and is easily reduced to powder.* Such are the properties of this substance, as far as they have been ascertained by M. Einhof.†

When 3840 parts of ripe peas were reduced to ashes, the residue weighed 112 parts. From these ashes Einhof extracted phosphoric acid, sulphuric acid, muriatic acid, alumina, silica, carbonate of lime, phosphate of lime, oxide of iron, and phosphate of ammonia and magnesia.‡

Braconnot analyzed peas in 1827, and obtained

Skins	8·26
Starch	42·58
Legumin	18·40
Water	12·50
Animal matter, soluble in water, insoluble in alcohol . .	8·00
Pectic acid, with some starch .	4·00
Uncrystallizable sugar . .	2·00
Chlorophylle	1·20
Pulpy skeleton . . .	1·06
Bitter matter, soluble in water and alcohol	a trace
Carbonate of lime . . .	0·07
Phosphate of lime and potash, vegetable acid saturated with potash	1·93
	100·00§

8. The seeds of the *vicia faba*, a small bean, becoming blackish when ripe, and used as an article of food, have likewise been examined by Einhof. The analysis was conducted in the same way as

* Einhof remarks, that he has seen the gluten of wheat assume this appearance. I have observed the same thing twice. In both cases the wheat was very inferior in quality, and had been the growth of a very rainy season.

† Gehlen's Jour. vi. 124. ‡ Ibid. 132.

§ Ann. de Chim. et de Phys. xxxviii. 79.

his other experiments already described. From 3840 parts of the ripe beans he obtained the following substances :—

Volatile matter . . .	600
Skins	386
Starchy fibrous matter . .	610
Starch	1312
Vegeto-animal matter . .	417
Albumen	31
Extractive, soluble in alcohol .	136
Gummy matter . . .	177
Earthy phosphate . . .	37½
Loss	133½
	3840*

Fourcroy and Vauquelin, who made experiments upon this substance likewise, found the ashes which it leaves when incinerated, to consist of the phosphates of lime, magnesia, potash, and iron, and of uncombined potash. They could detect no sugar in it.†

Vauquelin and Correa de Serra, made some experiments upon the bean in the year 1808.‡ They found in the *skins* of the bean, *tannin* striking a blue with the persalts of iron, *animo-vegetable matter* mixed with tannin, insoluble in water, but soluble in potash. The cotyledons contained a sweet-tasted substance, starch, legumin, albumen, an uncombined acid, with carbonate of potash, phosphates of lime, magnesia, and iron.

The *germen* of the bean contained white tallow, legumin, albumen, phosphate of lime, and peroxide of iron.

9. *Kidney beans*, which are the seeds of *phaseolus vulgaris*, have been likewise analyzed by Einhof. They are characterized by the great proportion of animo-vegetable matter which they contain. From 3840 parts of these beans Einhof obtained the following substances :—

Skins	288
Starchy fibrous matter . .	425
Starch	1380
Animo-vegetable matter, not quite free from starch . . .	799
Extractive	131
Albumen, with some vegeto-animal matter	52
Mucilage	744
Loss	21
	3840§

They were again analyzed by Braconnot,‖ in 1827, who obtained

* Gehlen's Jour. vi. 136. † Ann. de Mus. d'Hist. Nat. No. xxxvii. 9.
‡ Ann. de Chim. et de Phys. xxxv. 57. § Gehlen's Jour. vi. 545.
‖ Ann. de Chim. et de Phys. xxxiv. 85.

Husks	7
Starch	42·34
Water	23·00
Legumin	18·20
Animal matter soluble in water, insoluble in alcohol	5·36
Pectic acid with legumin and starch	1·50
Fatty matter	0·70
Pulpy skeleton	0·70
Incrystallizable sugar	0·20
Phosphate of lime and potash, carbonate of lime, vegetable acid united to potash	1·00
	100·00

Vauquelin analyzed a species of black kidney bean from the Isle of France. They furnished a dark-brown infusion, which left after evaporation a black residue mixed with grey crystals. If these crystals be picked out, dissolved in water and crystallized a second time, we obtain them in a colourless state. They are very volatile, when distilled give out ammonia, and are neither soluble in alcohol nor ether. The solution of these crystals strikes a green with the salts of iron, and lime water changes that colour into purple-red. The black substance which accompanies these crystals contains also azote. When dry it has a brilliant black colour, and is soluble unaltered in sulphuric acid.*

10. *Lentiles.* To Einhof, also, we are indebted for the analysis of the seeds of the *ervum lens.* From 3840 parts he obtained the following substances:—

Fibrous matter	720
Albumen	44
Earthy phosphates, with a little albumen	22
Extractive, soluble in alcohol	120
Gummy matter	230
Starch	1260
Vegeto-animal matter	1433
Loss	11
	3840†

Here the proportion of animo-vegetable matter is still greater than in the kidney bean.

Lentiles were examined by Fourcroy and Vauquelin, but whether the same species as the preceding, they do not put it in our power to determine, as they omit the botanical name. The liquid in which the flour of these seeds was macerated was not acid: it had a slight and rather disagreeable taste, and was precipitated copiously by

* Ann. de Chim. et de Phys. xxxvii. 173. † Gehlen's Jour. vi. 542.

infusion of galls, chlorine, and sulphate of iron. In short, it exhibited nearly the same phenomena as are described by Einhof. When the flour of lentiles is digested in alcohol, the liquid assumes a greenish-yellow colour, and a bitter acrid taste. When distilled it has the odour of vanilla very strongly, but acquires a disagreeable smell when mixed with water. The residue is greenish-yellow, has the appearance of a thick solution of soap, and a green oil swims upon the surface. The pod of the lentiles contains a portion of tannin.*

11. *Citrus aurantium*, the *orange*, and *citrus medica*, the *lemon*. These fruits are too well known to require any description. Though several parts of them are employed both in medicine, and in domestic economy, they have not yet been subjected to a rigid chemical analysis. The bitter oranges contain a peculiar bitter principle, which communicates the agreeable flavour that characterizes marmalade. It is soluble in water and weak alcohol. It precipitates the persalts of iron of a deep-brown colour. It does not precipitate tartar emetic, nor protochloride of tin. But the salts of lead and corrosive sublimate throw it down abundantly. It amounts to about 18 per cent. of the weight of the dry rind of the bitter orange.

Unripe bitter oranges were examined by Lebreton, who found in them

1 A volatile oil
2 A fatty saponifiable oil
3 Chlorophylle
4 Hesperidin
5 Bitter principle
6 Gum
7 Lignin
8 Albumen
9 Gallic acid, trace
10 Citric and malic acids, partly combined with potash
11 Sulphate and muriates.

The ash contained carbonate, sulphate, and muriate of potash, carbonate and phosphate of lime, silica, and a trace of iron.†

Lemon juice, according to Proust contains

Water	97·51
Citric acid	1·77
	99·28

Besides bitter principle, gum and malic acid to the amount of 0·72 per cent.

12. *Prunus cerasus* &c., the *cherry*, &c. Berard has analyzed the unripe and ripe cherry, and obtained the following results:—

* Annales de Mus. d'Histoire Naturelle, No. xxxvii. 10.
† Jour. de Pharmacie, xiv. 377.

	Reine Claude.		Cherry.	
	Unripe.	Ripe.	Unripe.	Ripe.
Chlorophylle . .	0·27	—	0·05	—
Sugar . . .	0·63	11·61	1·12	18·12
Gum . . .	4·22	4·85	6·01	3·23
Vegetable fibre .	3·01	1·21	2·44	1·12
Albumen . .	0·41	0·93	0·21	0·57
Malic acid . .	0·08	1·10	1·75	2·01
Lime . . .	trace	trace	0·14	0·10
Water . . .	90·31	80·24	88·28	74·85
	98·93	99·94	99·00	90·00

13. *Amygdalus communis*, the *almond*, *peach* and *apricot* trees. These three trees considered in a botanical point of view are identical, though the fruits are essentially different. It has been suggested by Mr Knight, that this difference is the result of culture. In the peach and apricot, the outer rind or husk of the kernel has been converted into a delicious fruit, while in the almond the fruit lies within the stony covering, the husk being harsh and not fit for eating.

The apricot and peach were analyzed by M. Berard, both in an unripe and ripe state, and found composed of

	Apricot.		Peach.	
	Unripe.	Ripe.	Unripe.	Ripe.
Chlorophylle . .	0·27	—	0·04	—
Colouring matter .	—	—	—	0·10
Sugar . . .	0·63	11·61	trace	16·48
Gum . . .	4·22	4·85	4·10	5·12
Vegetable fibre .	3·01	1·21	3·61	1·86
Albumen . .	0·41	0·93	0·76	0·17
Malic acid . .	1·07	1·10	2·70	1·80
Lime . . .	0·08	0·06	trace	trace
Water . . .	90·31	80·24	89·39	74·87
	100·00	100·00	100·00	100·40

There are two varieties of almond, the *bitter* and the *sweet*. *Bitter almonds* were examined in 1817 by Vogel.* The husk amounted to 8·5 per cent. of the whole. When the almonds were pounded and heated in order to coagulate the albumen, 28 per cent. of a fixed oil (containing no prussic acid) might be obtained by expression. But the whole of the fixed oil contained in the almonds could not be obtained in this way. The expressed residue being treated with boiling water gave out sugar and gum, and during the boiling, the oil containing hydrocyanic acid came over. To separate

* Schweigger's Jour. xx. 59.

the gum from the sugar, the decoction was evaporated to dryness and treated with alcohol, which dissolved the sugar but left the gum. The sugar amounted to 6·5 per cent. It was easily fermented, but could not be made to crystallize. The gum weighed 3 per cent of the almonds analyzed.

The matter exhausted of every thing soluble in boiling water, was treated with a dilute solution of caustic potash, which took up a quantity of albumen, after which drops of a fixed oil made their appearance on the surface of the liquid. The albumen weighed 30 per cent. and the vegetable fibre 5 per cent. The following table shows the substances extracted by Vogel, from 100 parts of bitter almonds

Husk	8·5
Fixed oil	28·0
Albumen	30·0
Sugar	6·5
Gum	3·0
Lignin	5·0
Heavy volatile oil	—
Hydrocyanic acid	—
	81

From the experiments of Robiquet and Boutron-Charlard,* there is reason to conclude that the volatile oil of bitter almonds does not exist ready formed, but makes its appearance during the processes to which the almonds are subjected. When bitter almonds deprived of their fixed oil by expression are digested in alcohol, a peculiar crystallizable substance is dissolved, to which they have given the name of *amygdalin*, and which has been described in a preceding Chapter of this volume. Sweet almonds do not contain any amygdallin.

Sweet almonds were analyzed by M. Boullay, in 1817,† who obtained

Water	3·5
Husk	5·0
Fixed oil	54·0
Albumen	24·0
Liquid sugar	6·0
Gum	3·0
Fibrin	4·0
Acetic acid and loss	0·5
	100

14. *Pyrus communis* and *pyrus malus*. The fruits of these well known trees are distinguished by the names of *pear* and *apple*.

Pears were examined by Berard, and found to contain the very same constituents as peaches and apricots. The following table exhibits the results of his analysis. The first column gives the

* Ann. de Chim. et de Phys. xliv. 352. † Ibid. vi. 406.

constituents of fresh and ripe pears; the second, of pears kept for sometime, which had lost a little carbon converted into carbonic acid by the oxygen of the air; the third column exhibits the constituents of the same pears in a state of putrefaction.

	Ripe and Fresh.	Kept for some time.	Putrid.
Chlorophylle . . .	0·08	0·01	0·04
Sugar	6·45	11·52	8·77
Gum	3·17	2·07	2·62
Lignin	3·80	2·19	1·85
Albumen . . .	0·08	0·21	0·23
Malic acid . . .	0·11	0·08	0·61
Lime	0·03	0·04	trace
Water	86·28	83·83	62·73
	100·00	99·65	76·85

Neither pears nor apples assume a blue colour when treated with iodine, showing that they do not contain starch. It is obvious from the black colour struck frequently when pears or apples are cut with a knife, that they contain also tannin, or gallic acid, or both. They contain likewise pectic acid and malate of potash.

The fermented juice of apples is called *cyder*. It is specifically heavier than water, assumes a brown colour, when concentrated by evaporation, and deposits a blackish-brown powder, and leaves a thick brown syrup. Cyder contains alcohol, incrystallizable sugar, gum, extractive, malic acid, bimalate of potash, malate of lime, a trace of phosphate of lime, and of sulphates and muriates.*

15. *Ribes grossularia*, *nigrum*, and *rubrum*. The fruits of these well known species of ribes are distinguished by the names of *gooseberry*, *black currant*, and *red currant*. Gooseberry and currant bushes are distinguished by the *prickles* which are present in gooseberry, and wanting in currant bushes.

Green gooseberries have been analyzed by Berard, who examined the berries both before they were ripe, and when ripe. The constituents found in the two states were the following :—

	Unripe.	Ripe.
Chlorophylle . .	0·03	—
Sugar . . .	0·52	6·24
Gum . . .	1·36	0·78
Albumen . . .	1·07	0·86
Malic acid . .	1·80	2·41
Citric acid . .	0·12	0·31
Lime . . .	0·24	0·29
Fibrin, (including the seeds)	8·45	8·01
Water . . .	86·41	81·10
	100·00	100·00

* Payenstecher, Schweizer Naturwiss. Anzeiger, Jahrg. iv. 89.

16. *Vitis vinifera.* *Grapes*, the well known fruit of this plant have not yet been subjected to a rigid chemical examination. The expressed juice of grapes, according to Scheele, contains no other acid but the tartaric, a statement which has been confirmed by Braconnot. Berard found in this juice from ripe grapes, an odoriferous substance, sugar, gum, albumen, malic acid, and malate of lime, tartaric acid and tartrate of lime.

17. *Mangifera indica*, or *domestica.* The fruit of this tree, the *mango*, is a well known fruit of India, varying from the size of an apricot to that of a Bonchretien pear. It is oblong, subreniform, and marked by a longitudinal sulcus, which extends over $\frac{3}{4}$ths of the fruit. Its skin is soft and smooth, and has a yellowish colour. When the mango is ripe, this skin is easily removed, and the fleshy part of the fruit is exposed to view, having an orange-yellow colour, full of juice, and having a very sweet and acidulous taste. The fleshy part of the fruit is full of long filaments, implanted in the envelope which covers the seed of the mango. This seed is kidney-shaped, and is covered with a kind of white skin. It has a disagreeable styptic taste, similar to the fruit of the horse-chesnut tree.

The fleshy part of the mango contains a great quantity of crystallizable sugar, citric acid, and gum. The aromatic principle which resides in the skin of the fruit is very fugitive, and cannot be procured by distillation.

The seed of the mango has been analyzed by M. Avequin.* He extracted from it the following constituents:—

Albumen	0·04
Gallic acid	10·00
Tannin	0·37
Starch	36·93
Gum	2·88
Stearic acid	2·34
Green resin	0·28
Brown resin	0·37
Butter	1·74
Extractive colouring matter, tannin, and gallic acid	9·09
Lignin	5·89
Water	28·59
	98·52

The quantity of gallic acid in the seeds of the mango is very remarkable. M. Avequin proposes the following method of extracting it:

Take a pound of seeds of mango, reduce it to powder, and pass the powder through a seive. Digest this powder for 12 hours in 4 lbs. of water. The temperature of the water should not exceed

* Ann. de Chim. et de Phys. xlvii. 20; and Jour. de Pharmacie, xvii. 421.

122°. Filter and make a second infusion similar to the first, with 2 lbs. of water. Subject the undissolved matter to pressure, to extract all the liquid from it. Mix together all these liquids and evaporate them over the vapour bath, till the whole does not exceed a pound. Clarify with two whites of eggs beat up in eight ounces of water. Then filter and evaporate the liquid to the consistence of treacle, on this residue pour 3 lbs. of alcohol of the specific gravity 0·837, and stir the whole strongly with a glass rod. Let the whole settle for 12 hours and then filter. Put this alcoholic solution into a distilling apparatus, and distil till only 6 ounces of liquid remain in the retort. Leave it at rest. In 48 hours the gallic acid will crystallize. Collect the crystals formed. Let them drain, dissolve them in distilled water, and add to the solution $\frac{1}{8}$th of their weight of animal charcoal, previously digested in muriatic acid, and carefully washed. Boil for 10 minutes, filter, and evaporate. The gallic acid will now form pure crystals.

We may obtain the gallic acid from the seeds of the mango without employing alcohol. The preceding process is followed:—We evaporate the clarified aqueous solution to six ounces, and set it aside for 3 or 4 days. The acid crystallizes, and may be purified by the process just stated.

Gallic acid exists in much greater quantity in the seed of the mango than in any other known vegetable, and if it ever should become an object of commerce, it is from these seeds that it ought to be extracted.

The stearic acid was obtained by digesting the seeds, previously exhausted by water, in boiling alcohol. The greater part of the alcohol was distilled, and the remainder being left at rest, the stearic acid gradually separated from it and floated on the surface of the liquid. It was washed with water, and then filtered hot through blotting paper.

It was soluble in hot absolute alcohol, ether, and acetic acid of the specific gravity 1·063, and crystallizes as the solution cools. When freed from a brown resin which it contained, at first it was white, solid, without taste or smell, melted at 158°, and crystallized in silky needles on cooling. It was insoluble in water, soluble in fixed oils, and readily formed soap by uniting it with bases.

The substance called butter by M. Avequin was extracted from the seeds previously exhausted by water and alcohol. They were treated with ether. The ether being distilled off, a matter similar to hog's lard remained in the retort, having a yellow colour. It was washed with alcohol of 0·837 to remove the colouring matter. It was then quite white, melted at 86°, was soluble in hot ether, but insoluble in rectified spirits. It exactly resembled butter of cocao.

18. *Amomum granum paradisi.* The fruit of this species of ginger, known by the name of *grains of paradise*, is used in India, where the plant grows naturally, mixed with betel, to promote digestion. The taste is agreeable. When squeezed in the mouth the grains produce a pleasant coolness. They are angular, reddish-

brown externally, but white within. They have an aromatic odour. They are arranged in two rows in each of the three compartments of a capsule, having nearly the shape of a fig.

These grains have been analyzed by M. Willert. When distilled they give 0·5 per cent. of their weight of a volatile oil, of a light-yellow colour, and a camphory smell, and a hot penetrating taste. It is soluble in about 9 times its weight of anhydrous alcohol, and is pretty soluble in water.

Alcohol extracts from the grains of paradise, a notable quantity of resin and extractive. If we mix the solution with water, and distil off the alcohol, the resin is deposited while the extractive remains in solution. This resin weighs 3·4 per cent. It is brown coloured and always remains soft. It has no smell, but its taste is exceedingly acrid and burning, and remains long in the mouth. The weight of the extractive which remains dissolved in the water is 1·15 per cent. It has a brownish-black colour, and when dissolved in water leaves apotheme. It precipitates protosulphate of iron, of a blackish-green colour; the protochloride of iron, of a deep brown; the protochloride of tin, brown; and the acetate of lead, yellow.

The residual portion of the grains contains so much mucilage that it swells in water, and is converted into a thick mass, which can neither be filtered nor separated by decantation from the insoluble lignin. The total weight of these two substances is 83 per cent.*

19. *Piper nigrum.* This is the name of the plant which produces common *pepper*. It is a shrub which grows in India. The seeds, are berries, round, hard, having an aromatic smell, and a hot acrid taste. These berries constitute pepper. The unripe berries are the common *black* pepper, while the ripe berries deprived of their epidermis constitute *white* pepper.

Pepper was examined in 1819, by M. Orstedt, who detected in it a substance to which he gave the name of *piperin*, and which has been described in a preceding Chapter of this volume. In 1821, M. Pelletier† published an elaborate examination of pepper. He showed that it contained the following constituents:

Piperin
A solid very acrid oil
A balsamic volatile oil
A gummy coloured matter
Extractive, similar to that obtained from leguminous seeds
Malic and tartaric acids
Starch
Bassorin
Lignin
Earthy and alkaline salts in small quantities.

M. Pelletier showed that the *piperin* did not possess alkaline characters as Orstedt had supposed, but that it was a peculiar

* Berzelius, Traité de Chimie, vi. 293.
† Ann. de Chim. et de Phys. xvi. 337.

principle. He found too, that pepper owed its peculiar taste to a volatile oil. This I had shown many years before.*

20. *Piper longum.* Long pepper is the fruit of the *piper longum*, a shrub which is a native of Bengal. It was in it that Orstedt discovered *piperin*. M. Dulong d'Astafort afterwards analyzed long pepper, and obtained

Piperin
An acrid fatty matter
Volatile oil
Extractive
Gum
Starch
Bassorin in abundance
A malate and some other salts.†

21. *Piper cubeba.* Cubebs are the fruit of the *piper cubeba*, a perennial shrub which grows in the Philippine islands, in Java, Guinea, and the Isle of France. The cubebs are berries, round, dry, and of the size of pepper corns. They have a blackish-grey colour, wrinkled, and stand upon short peduncles. The external bark, easily broken, covers a blackish skin, which envelops a white and oleaginous kernel. The smell is agreeable and aromatic, the taste aromatic and rather acrid. These berries were examined by Vauquelin,‡ in 1822. He extracted from them the following substances :—

1 A volatile oil, which was nearly solid
2 Resin, like that from balsam of copaiva
3 Another coloured resin
4 A coloured gummy matter
5 Extractive, like that in leguminous plants
6 Some saline substance.

This fruit has been lately examined by Cassola,§ who has obtained from it a peculiar substance, to which he has given the name of *cubebin*. It may be obtained in the following way :—Boil 1 part of cubebs with 4 parts of alcohol, filter, press out the liquid, and distil off the alcohol. Mix the liquid remaining in the retort, while boiling hot, with acetate of lead. Wash and dry the precipitate, and treat it with alcohol. When the alcoholic liquid is evaporated, the cubebin is deposited.

It has a green colour, and the consistence of turpentine. Its taste is at first sweet, and then burning, like that of cubebs. It dissolves readily in anhydrous alcohol, and in ether, but it is almost insoluble in boiling water, though it gives its taste to that liquid. It melts at 68°, and at 86° it begins to boil, and may be volatilized in a white smoke, which forms a syrupy liquid. It is quite neutral, and is the substance that gives cubebs their peculiar properties. It congeals at 5°.

* Nicholson's Jour. ii. 7. † Jour. de Pharmacie, xi. 52.
‡ Annals of Philosophy (second series), iii. 202. § Jour. de Ch. Med. x. 685.

Cubebs have been lately analyzed by M. Monheim.* He obtained

1 Waxy matter	3
2 Green volatile oil	2·5
3 Yellow volatile oil	1·0
4 Cubebin	4·5
5 Balsamic resin	1·5
6 Chloride of sodium	1·0
7 Extractive	6·0
8 Lignin	65·0
	84·5

22. *Capsicum annuum.* The fruit of this plant, which is a native of India, but cultivated also in America and the West Indies, constitutes what is called *Guinea* or *Cayenne pepper.* It is smooth and elongated, of a lively-red or yellow colour, vesicular, bilocular, of very varying shape, and inclosing numerous flat seeds. It has no smell, but its taste is bitter, acrid, and burning.

Guinea pepper was first analyzed by Bucholz,† who obtained the following constituents:—

Wax	7·6
Acrid soft resin	4·0
Bitter aromatic extractive	8·6
Extractive with some gum	21·0
Gum	9·2
Fibrin	28·0
Albumen	3·2
Water	12·0
	93·6

In 1817 it was analyzed by Braconnot.‡ He obtained from it the following constituents:

Starch	9
A very acrid oil	1·9
Wax with red colouring matter	0·9
Gum of a peculiar nature	6·0
Animalized matter	5·0
Citrate of potash	6·0
Lignin	67·8
Muriate of potash, Phosphate of potash	3·4
	10·0

The acrid oil is the constituent to which the Guinea pepper owes its peculiar taste. It has been called *capsicin.* When heated it melts into a very fluid substance, and when the temperature is raised still higher, it is dissipated in fumes. Half a grain of it volatilized in a large room, causes all who respire the air of the room to cough and sneeze. When long exposed to the air and light, it becomes hard. Chlorine whitens it. It is slightly soluble in water, espe-

* Jour. de Pharmacie, xx. 403. † Taschenbuch, 1816, 1.
‡ Ann. de Chim. et de Phys. iv. 122.

cially when mixed with the other principles of the Guinea pepper. The solution has the acrid and burning taste of the pepper. It is very soluble in alcohol, ether, oil of turpentine, and the caustic alkalies. These solutions have a reddish-brown colour. With barytes it precipitates under the form of an insoluble compound, having an acrid taste. It is slightly soluble in vinegar.

23. *Myrtus pimento.* The fruit of this tree, which is a native of the West Indies, is known in this country by the name of *Jamaica pepper*. The berries are pulled and dried before they are ripe. They are wrinkled, a little larger than the grains of black pepper, globular or oblong, and of a deep-brown colour. They have an odour and taste, which seems to be a mixture of that of pepper, cinnamon, and cloves.

It was subjected to a chemical analysis by Bonastre,* who examined separately the skin and the kernel.

Cold alcohol extracts, from the envelope, tannin, and a soft green resin, which is deposited during the evaporation of the alcohol. Boiling alcohol being applied afterwards, dissolved a little green resin and a solid fat oil, which was deposited in flocks during the cooling of the alcohol.

The green resin has the burning and aromatic taste which characterizes Jamaica pepper, and a rancid odour, but somewhat analogous to that of cloves. It is no doubt a mixture or compound of volatile oil and resin, and probably contains other substances besides. The tannin dissolved in alcohol, strikes a green colour with the persalts of iron, and precipitates tartar emetic. The husks, after being exhausted by alcohol, swell considerably when put into ammonia, and the alkali dissolves a brown matter, which precipitates in brown flocks.

Jamaica pepper when distilled yields a volatile oil. Bonastre employed the same method to analyze the husk and the kernel of the seeds. The following table shows the result of these analyses.

	Husks.	Kernels.
Volatile oil	10·0	5·0
Soft green resin	8·0	2·5
Solid fat oil	0·9	1·2
Extract containing tannin	11·4	39·8
Gum	3·0	7·2
Brown colouring matter extracted by potash	4·0	8·8
Resinous matter	1·2	3·2
Extract containing sugar	3·0	8·0
Malic and gallic acids	0·6	1·6
Lignin	50·0	16·0
Ashes containing salts	2·8	1·9
Moisture	3·5	3·0
	98·4	98·2

* Jour. de Pharmacie, xi. 180.

24. *Tamarindus Indica.* *Tamarinds* consist chiefly of a pulpy matter which fills the pods of the *tamarindus Indica*, and covers the seeds. It is brought to Europe preserved in sugar. We are indebted to Vauquelin for an analysis of this substance, published however at a very early period of his chemical career. By treating the pulp of tamarinds, such as they are sold by the apothecaries, first with cold water, and afterwards with hot, he separated the following substances:—*

Supertartrate of potash . .	300
Gum	432
Sugar	1152
Jelly	576
Citric acid	864
Tartaric acid	144
Malic acid	40
Feculent matter . . .	2880
Water	3364
	9752

Scheele found no citric acid in the pulp of the tamarind; he found only tartaric acid.

25. *Juniperus communis.* This shrub, which grows wild in Scotland and other northern countries, bears the well-known fruit, called *Juniper berries.* They contain a volatile oil to which they owe their taste and their value, being employed to communicate that peculiar flavour to Dutch gin. It exists chiefly in the green berries. In the berries which have become black that oil is converted into resin. When the berries have a deep blue colour they contain a good deal of sugar, but in the dried black berries it has almost disappeared.

Juniper berries were analyzed by Trommsdorf,† who found in the berries, just on the point of being ripe,

Volatile oil	1·0
Brittle wax	4·0
Green resin	10·0
A peculiar species of sugar .	33·8
Gum	7·0
Lignin	35·0
	90·8

The volatile oil has been described in a preceding Chapter of this volume.

The sugar crystallizes with difficulty in grains. It has a honey-yellow colour. Its taste is less sweet than that of grapes. It dissolves in boiling alcohol, and is mostly deposited as the liquid cools. It is insoluble in ether. It ferments readily when its aqueous solution is mixed with yeast. This sugar, as obtained from juniper berries, is mixed with a peculiar extractive substance, having an

* Ann. de Chim. v. 92. † Taschenbuch, 1822, p. 43.

acrid and aromatic taste, and with acetate of potash. This sugar may be obtained by macerating the bruised berries in cold or warm water.

Juniper berries were analyzed also by M. Nicolet, who obtained*

A volatile oil
Sugar
Wax
Resin.

The wax was composed of

Carbon . .	65·400	or 13 atoms
Hydrogen .	7·3227	or 8½ atoms
Oxygen . .	27·2773	or 4 atoms.
	100	

The resin was crystallized and composed of

Carbon . .	75·04	or 5 atoms
Hydrogen . .	5·1037	or 2 atoms
Oxygen . .	19·8563	or 1 atom.
	100	

26. *Pimpinella anisum.* The seeds of this umbellated plant, which is a native of the Levant, are well known by the name of *anise.* It is chiefly cultivated in Spain and Malta, whence the anise seed is imported into this country. It is cultivated also in the south of England. Anise seeds have an aromatic smell and a pleasant warm taste, accompanied with a considerable degree of sweetness.

These seeds were chemically examined by M. Brandes. When digested in boiling alcohol till every thing soluble is taken up, the solution being left to itself, after distilling off the greatest part of the alcohol, deposits 0·125 per cent. of concrete fixed oil, together with chlorophylle. When still farther concentrated it yields 3·55 per cent. of a green-coloured fat oil, showing from its taste and smell that it contains some volatile oil of anise. This fat oil has a butyraceous consistency. It dissolves readily in alcohol, leaving 0·175 of a brown residue, mixed with malate of lime and malate of potash. Caustic alkalies convert it into soap, letting fall a white flocky substance which has not been examined. The solution remaining, after the separation of the oils, gave, by evaporation, a brown extract soluble in water. From this extract anhydrous alcohol dissolved a small quantity (0·15) of a resin, and 0·4 of bimalate and binacetate of lime. The residue, insoluble in anhydrous alcohol, was completely soluble in water.

Alcohol precipitated from that solution 0·65 of grey flocks, which became black when dry. This substance contains azote, for when heated it gives off ammonia. It is very soluble in water, and the solution, which has a brown colour, froths much when agitated.

* Jour. de Pharmacie, xvii. 310.

It is precipitated by nitrate of silver, acetate of lead, and infusion of nut-galls.

The liquid remaining, after the precipitation by alcohol, gave, when evaporated, incrystallizable sugar, mixed with extractive. This sugar amounted to 1 per cent. and fermented readily when mixed with yeast.

What remained of the anise seeds after the action of alcohol, was boiled in water till every thing soluble in that liquid was taken up, and the decoctions evaporated to the consistence of an extract. This extract was taken up by a little water, and alcohol added as long as a precipitate continued to fall. A substance was in this way separated, which, when dry, was deep-brown, hard, had a vitreous fracture and a faint smell and taste. It was gum, mixed with a small quantity of phosphate of lime and malate of potash. It amounted to 6·5 per cent.

The residual liquid being left to spontaneous evaporation, deposited 1 per cent. of bimalate of potash in small granular crystals; and when evaporated to dryness, left 6·5 per cent. of brown matter having a bitter, acrid, and saline taste. It absorbs moisture from the air, and dissolves completely in weak alcohol. But it is insoluble in absolute alcohol and in ether. Its aqueous solution is not precipitated by corrosive sublimate; but it is by nitrate of mercury and diacetate of lead. Nitrate of silver and sulphate of copper throw it down in brown flocks. It is precipitated abundantly by infusion of nutgalls. It consisted of extractive, salts, and a substance precipitable by infusion of nutgalls.

The residue of the seeds thus exhausted, first by alcohol and then by water, was treated with muriatic acid which dissolved phosphate of lime and a vegetable acid salt of lime, coloured brown by a little extractive. The weight of the whole of this mixture was 1·97, and that of the phosphate of lime 1·35.

The residue was now treated with a weak boiling solution of caustic potash, and left an insoluble residue of 35·9 per cent of lignin. The alkaline solution neutralized by acetic acid gave a precipitate weighing 8·6 per cent. When dry it was deep brown. Its taste was weak but astringent. It was insoluble in water, alcohol, ether, and acids; but soluble in caustic alkalies and in alkaline carbonates by the assistance of heat. Brandes has distinguished this substance by the name of *ulmin of the anise*.

The liquor precipitated by acetic acid being evaporated and treated with alcohol, left 2·9 per cent. of a reddish-brown substance, destitute of smell, insipid, and very soluble in water. It may consist of starch, altered by the processes of the analysis. Brandes has given it the name of *gummoin*. But it seems to have little analogy with gum.

Besides the above-mentioned substances, Brandes found 3·5 of silicate of iron, 3 of volatile oil, and 23 of water. The following table exhibits the constituents which he obtained :—

Concrete fixed oil . . .	0·125
Green fat oil	3·550
Resin	0·150
Bimalate and binacetate of lime	0·400
Azotized substance . . .	0·650
Sugar	1·000
Gum	6·500
Bimalate of potash . . .	1·000
Extractive, with salts, &c. .	6·500
Phosphate of lime, &c. . .	1·970
Lignin	35·900
Ulmin of anise . . .	8·600
Gummoin	2·900
Silicate of iron . . .	3·500
Volatile oil	3·000
Water	23·000
	97·745

27. *Sinapis alba* and *nigra*. These two species, both natives of Great Britain, and too well known to require description, produce the seeds in such general use under the name of *mustard*. The *nigra* produces the common black mustard. The seeds of the *alba* are largest and of a light yellow colour. When these seeds, of either species, are bruised and their fixed oil expressed, the residue constitutes the common condiment well known by the name of *Durham mustard*.*

The *sinapis alba* seeds, according to the analysis of John, contain

1 An acrid volatile oil
2 A yellow fixed oil
3 Brown resin
4 A very little extractive
5 A little gum
6 Lignin
7 Albumen
8 Phosphoric acid and salts.†

The constituents of the seeds of *sinapis nigra*, or common mustard, are much the same.

MM. Henry and Garot, several years ago, announced that they had extracted from the seeds of white mustard a peculiar acid, which they distinguished by the name of *sulphosinapic acid*, the properties of which they described, and among other peculiarities

* The mustard of the shops is said to be often mixed with wheat flour and cayenne pepper to heighten the flavour. It is said also to contain salt, but I could detect none in what is sold in Glasgow. When mustard is dried, it assumes a very deep brownish-orange colour. Alkalies restores the yellow colour. Muriatic acid destroys the colour altogether and forms a complete solution. I could detect no turmeric nor cayenne pepper in the specimen which I examined.

† Chem. Schr. iii. 153.

they stated that it struck a red with the persalts of iron. This observation led M. Pelouze to examine mustard. He found in it sulphocyanate of lime, and concluded that the acid described by Henry and Garot was hydrosulphocyanic. These observations induced Henry and Garot to resume their examination of mustard. They found that it neither contained sulphocyanite of calcium, nor sulphosinapic acid, but that there exists in it a peculiar crystallizable body, to which they gave the name of *sulphosinapisin;* but which has been shortened by Berzelius into *sinapin.* The method of procuring this substance and its characters, have been given in a preceding Chapter of this volume.

The observations of Henry and Garot have been confirmed and extended by Fauré, Robiquet, and Boutron-Charlard. These chemists have shewn that the volatile oil of mustard does not exist in the seeds of the plant, but that it is produced by the influence of water, like the volatile oil of bitter almonds. When mustard is treated first by alcohol and then by water, no volatile oil is obtained, and Fauré has shown that the seeds of *sinapis nigra* which yield most volatile oil, yields none whatever if they be distilled after having been moistened with acid or alkaline water. The same thing happens when we add to the water in which the mustard is macerating, a little acid or alkali before proceeding to distillation. It appears clearly, from the researches of these chemists, that sinapin is not the only substance in mustard which contributes to the production of the volatile oil, and Fauré has found that after the seeds of *sinapis nigra* have been freed from all their volatile oil by distillation, the decoction which remains in the alembic still contains sinapin.

Robiquet and Boutron-Charlard observed that if mustard, freed from its fixed oil by expression, be treated with ether, a red substance is dissolved analogous to fatty matter. It has an excessively acrid taste but no smell. It is not volatile. It is insoluble in alcohol, and may be freed by that liquid of the fat oil which the ether has dissolved along with it. If the ether employed contains a little acid, the acrid matter has the property of striking a red with the persalts of iron; and yet it does not contain the smallest trace of sinapin.

When mustard, after being exhausted by ether, is treated with alcohol, that liquid acquires a deep red colour, and when evaporated to the consistence of a syrup, we obtain crystals of sinapin which possess the property of striking a red with the persalts of iron.

If we boil the expressed juice with anhydrous alcohol, the solution assumes a greenish-yellow colour, and after a certain time gives crystals of sinapin which do not possess all the properties of the sinapin of Henry and Garot. Neither the alcoholic solution nor the residue contain an acrid body, showing that the substances obtained did not exist quite formed in the seeds, and that, being formed by the action of different re-agents, their composition is not quite the same.

Sinapin, extracted from mustard by alcohol alone, is in yellowish crystals, which give out a little fat oil when treated with ether. It is much less soluble in alcohol than sinapin obtained after a previous digestion of the seeds in ether. Its aqueous solution does not furnish crystals after a gentle evaporation, and leaves a yellow matter like a varnish, which detaches itself from the vessel in scales. It does not strike a red with the persalts of iron, and when mixed with alkalies emits no smell of the volatile oil of mustard. In other respects it agrees in its characters with the sinapin of Henry and Garot. Its composition, according to the analysis of Robiquet and Boutron-Charlard, is as follows:—

Carbon	54·0000
Hydrogen	10·6512
Azote	2·8392
Sulphur	9·3670
Oxygen	23·1426
	100·0000

These numbers do not correspond with the analysis of Henry and Garot. They lead to the following formula:—

45 atoms carbon . . .	= 33·75
53 atoms hydrogen . .	= 6·625
1 atom azote . . .	= 1·75
3 atoms sulphur . .	= 6
15 atoms oxygen . .	= 15
	63·125

Fautré, whose experiments were made chiefly on black mustard, found that it lost nothing of its acrid taste when digested in ether, and that the residue, mixed with water, gives, when distilled, volatile oil of mustard, just as happens to bitter almonds. The residuum, after digestion in ether, yields to alcohol, among other things, sinapin. But if we begin by treating black mustard with alcohol, it loses in consequence all its acrid taste, and we cannot obtain any volatile oil. The alcohol holds in solution sinapin and other substances.

If we treat black mustard reduced to powder with water, containing sulphuric acid or caustic potash, no volatile oil is formed, as has been already observed. But when we add acid to the alkaline liquid, or alkali to the acid one, a body precipitates which dissolves in boiling alcohol. The solution has an azure-blue colour, and when we evaporate, the dissolved body is left mixed with a little sinapin under the form of a green mass.*

Much still remains to be done to complete our knowledge of mustard. The facts above stated are at least curious and interesting.

28. *Anacardium longifolium.* The fruit of this tree, which grows

* See Jour. de Pharmacie, xvii. 267, 271, 279.

both in the East and West Indies, is called *cashew nut*, or Acajou. This fruit is an ovoid-shaped nut, flattened at the sides, or heart-shaped, containing an oleaginous kernel under a smooth, shining, brown bark, impregnated with a mucilaginous black juice, and adhering to the base of the calyx, which has become fleshy and turbinated when dry. The bark or husk of the fruit contains a very acrid oil. The kernel is sweet.

The juice of the husk, when spread upon linen or cotton cloth, produces an indelible black stain, like the stain of the *rhus radicans*. It is employed in India for marking linen. From the experiments of M. Vicira de Matos,* the husk contains

Much gallic acid
Tannin
Extractive
Gum resin
Chlorophylle.

The resinous matter is liquid at 59°, solid at 50°. Its taste is acrid.

29. *Cocos nucifera*. The fruit of this palm is well known under the name of *cocoa nut*. A detailed account of the management and products of this tree has been published by M. Le Goux de Flaix.† The outer coat is fibrous, and is formed in India into excellent cordage. The kernel contains a considerable portion of fixed oil, employed in India for lamps.‡

The cocoa nut has been analyzed by Brandes. Its three constituents are

Fibrous envelope . . .	0·49
Hard shell	0·21
Kernel	0·36
	1·06

The liquid contained in the hollow part of the nut is fluid but not perfectly limpid. Its taste is slightly sweet, and at the same time saline. Its specific gravity is 1·05. It contains 85 per cent. of water, and when heated it lets fall 2 per cent. of albumen. When it is evaporated to dryness and the residue treated with alcohol, a small quantity of resin is dissolved, together with an extractive substance, which is deliquescent and precipitable by infusion of nutgalls and the diacetate of lead. It amounts to 0·12 of the dry residue.

The matter insoluble in alcohol is only 0·02 of the weight of the residue. It is also precipitated by the infusion of nutgalls and the diacetate of lead.

This liquid contains likewise malate and phosphate of lime, and a small quantity of malate of magnesia.

* Jour. de Pharmacie, xvii. 625. He calls the tree *Anacardium occidentale;* but I presume it is the same with the *longifolia*, as it produces the cashew nut.

† Phil. Mag. xx. 316 ; and xxi. 77, 110.

‡ Tennant's Indian Recreations, ii. 282.

The kernel, or white portion under the shell, is the eatable portion of the cocoa nut. It contains

Pulpy fibres about 0·06
Crystallized tallow 0·25, which contains $\frac{1}{6}$th of its weight of elain
A little albumen
Gluten
Sugar
The same substances precipitable by infusion of nutgalls and diacetate of lead, which exist in the watery liquid of the nut.

It contains also phosphates, sulphates, and malates of potash and lime. The water contained in the kernel of cocoa nut amounts to 0·45.

Besides these constituents, it contains a notable quantity of fixed oil, which has been described in a preceding Chapter of this volume.

The liquid or milk of the cocoa nut was also analyzed by Bizio, in 1833.* He obtained

Water	95
Glycine	3·825
Zimome	0·750
Mucilage	0·25
	99·825

The glycine was crystallized, and considered by Bizio as identical with the orcin of Robiquet, described in a preceding Chapter. It is soluble in water and alcohol, crystallizes, is precipitated by subacetate of lead, and is incapable of fermenting.

In the kernel he found

Fixed oil	71·488
Zimome	7·665
Mucilage	3·588
Glycin	1·595
Yellow colouring matter .	0·325
Lignin	14·95
	99·311

30. *Quercus robor.* The fruit of the oak is well known under the name of *acorns*. Some experiments on the constituents of acorns have been published anonymously in the *Annals of Philosophy*.† 100 parts of acorns were found to contain

Starch	20·29
Insoluble matter . . .	18·00
Albumen	7·14
Tannin	2·85
Extractive and loss . .	51·72
	100·00

100 parts of acorns, exposed to a red heat, left 1·33 of ashes. These ashes consisted of $\frac{3}{4}$ths soluble salts, and $\frac{1}{4}$th insoluble. The soluble portion was composed of

* Jour. de Pharmacie, xix. 455. † Second Series, xii. 43.

Carbonate of potash	8·8
Potash	5·3
Sulphate of lime	0·5
Muriate of magnesia	0·4
	15·0

The insoluble portion consisted of

Silica	0·5
Protoxide of iron	0·1
Lime	3 4
Magnesia	0·5
Alumina	trace
Loss	0·5
	5·0

The author has not furnished us with the requisite data to judge of the accuracy of his analysis.

31. *Coumarona oderata.* The fruit of this tree, which is a native of Guiana, is known by the name of *tonka bean.* It is much used in order to give a peculiar aromatic flavour to snuff. It was subjected to a chemical analysis by MM. Boullay and Boutron-Charlard,* who obtained from it

1 A saponifiable oil
2 A crystallized substance called *coumarin*
3 Sugar
4 Free malic acid
5 Bimalate of lime
6 Gum
7 Starch
8 An ammoniacal salt
9 Fibrin.

The coumarin has been described in a preceding Chapter of this volume.

32. *Cucumis colocynthis.* The fruit of this plant, which is a native of Turkey and Nubia, is called *bitter cucumber*, and the pulp of it is much used in medicine under the name of *coloquintida.* The plant has much the habit of the *cucumber.* The fruit is a round berry about the size of a small orange, yellow and smooth on the outside when ripe; trilocular, each cell containing many ovate, compressed, whitish seeds enveloped in a white spongy pulp. When the fruit is ripe, it is peeled and dried in a stove, and in this state is imported into this country. When it is larger than a St Michael's orange, and has black acute-pointed seeds, it is not good.

It has no smell when dried; but has an extremely bitter, nauseous taste, and the pulp feels mucilaginous when chewed.

The pulp of the colocynth, which is employed in medicine, contains, according to the analysis of Meissner,†

* Jour. de Pharmacie, xi. 480.

† N. Tr. i. 22, as quoted by L. Gmelin. Handbuch der Theor. Chem. ii.1274.

Fat oil	4·2
Brownish-yellow resin	13·2
Colocynthite	14·4
Extractive	10·0
Gum	9·5
Pectic acid	3·0
Gummy extract	17·6
Phosphate of lime	2·7
Phosphate of magnesia	3·0
Lignin	19·0
Water	5·0
	101·6

The brownish-yellow resin was brittle, had a very bitter taste, and was insoluble in ether.

What has been called *colocynthin*, is a peculiar bitter principle, first noticed by Vauquelin.* An account of it has been given in a previous Chapter of this volume.

The 17·6 of gummy extract was obtained from the vegetable fibre by means of potash.

Braconnot made an analysis of the pulp of the colocynth. He obtained

Resin	4·3
Colocynthite	41·4
Pectic acid	18·6
Azotic substance	21·4
Acetate of potash	7·1
A deliquescent salt of potash, soluble in alcohol	7·1
	95·9

33. *Cucumis sativus.* The common *cucumber*, which is the fruit of this plant cultivated so commonly in our gardens, has been analyzed by Dr John, who found it composed of the following ingredients:—

Water	97·13
Substance similar to fungin	0·53
Soluble vegetable albumen	0·13
Resin	0·04
Extractive with sugar	1·66
Mucus, Phosphate of lime, Phosphate of potash, Phosphoric acid, Ammoniacal salt, A malate, Sulphate of potash, Muriate of potash, Phosphate of iron	0·5
	100·0†

* Jour. de Pharmacie, x. 416.

† Bouillon, Jour. de Phys. xxix. 3. Parmentier, Ann. de Chim. liii. 119.

34. *Cytisus laburnum.* The seeds of this plant, the common *laburnum* of our shrubberies, were examined in 1818 by Chevallier and Lassaigne.* They found in it the following constituents:—

1 A white fatty matter with a shade of green
2 Albumen
3 Cytisite
4 Chlorophylle
5 Malic and phosphoric acids
6 Malate of potash and lime
7 A minute quantity of silica.

The properties of the bitter substance called *cytisite*, have been given in a preceding Chapter of this volume.

35. *Datura stramonium.* The fruit of this plant, called *thorn apple*, as well as its leaves and roots, are employed in medicine. The plant is an annual, and originally a native of America, but long naturalized in our garden. Indeed, in the neighbourhood of London and other places in England, it is often met with wild, having made its way into fields from the neighbouring gardens. The fruit is a large roundish four-cornered capsule, beset with sharp awl-shaped spines, four-celled at the base, two-celled at the apex, and containing a great number of reniform compressed seeds.

Thorn apples were examined chemically by M. Brandes, who obtained from them

1 Chlorophylle
2 A butyraceous oil
3 A viscid oil
4 Wax
5 A resin insoluble in ether
6 Extractive
7 Sugar
8 Gum
9 Mucilage
10 An azotized substance insoluble in alcohol
11 Albumen
12 Apotheme
13 Lignin
14 Malates and phosphates
15 Salts of *daturina*.†

Succeeding chemists, not being able to succeed in obtaining any daturina from these fruits, denied its existence; and Brandes himself afterwards stated his belief, that what he had taken for a peculiar vegetable alkali, was nothing else than phosphate of magnesia.

Lindbergen showed that the narcotic properties of the thorn apple were precisely similar to those of the *atropa belladonna* and *hyoscyamus niger*. Hence it was reasonable to infer, that all the three contained the same narcotic principle.

Brandes had detected a vegetable alkali in *atropa belladona*, to

* Jour. de Pharmacie, iv. 340. † Repert. viii. 1.

which he gave the name of *atropina*. Succeeding experimenters, not being able to find this alkali in *deadly night-shade*, denied its existence. But Runge showed, that the reason of their not finding it was, that they had employed a caustic alkali to separate it, which alkali has the property of decomposing atropina. By employing magnesia, he obtained a vegetable alkali from belladonna, henbane, and thorn apple, and he has shown the properties of these three bodies to resemble each other so closely, that there is reason for believing that all the three are identical. The account of the properties of this vegetable alkali has been given in a preceding part of this volume, while treating of *atropina*.

36. *Laurus nobilis*. The *laurel*, is a native of Italy, and other countries in the south of Europe, but is cultivated in this country and is a common shrub in our shrubberies, constituting a beautiful evergreen. In this country, it is only a shrub, but in Italy, it reaches the size of a small tree, the berry of the laurel is of an oval shape, fleshy, and of a dark-purple, or almost black colour. It contains a considerable quantity of insipid fixed oil, which is extracted by expression, or by boiling the berries in water.

These berries were subjected to a chemical analysis by M. Bonastre.* He obtained

Volatile oil	0·8
Laurin	0·5
Green fat oil	6·4
Soft crystallized oil	3·5
Soft resin	0·8
Starch	12·95
Gum	8·6
Mucilage	3·2
Uncrystallizable sugar	0·2
Albumen	trace
Lignin	9·4
Ashes	0·72
Water	3·2
	50·07

Besides these constituents, the berries of the laurel contain a free acid.

The *laurin* of Bonastre has an acrid and bitter taste, and its smell is analogous to that of laurel oil. It is insoluble in water and but little soluble in cold alcohol. Ether and boiling alcohol dissolve it much better. It crystallizes from its solutions in needles, resembling asbestus, and which grate under the teeth like gypsum or sulphur. When heated, it melts and may be volatilized without leaving any residue. Sulphuric acid gives it a yellow, and at last a reddish-yellow colour. It liquefies in cold nitric acid, and then swims like an oil upon the surface of the liquid.

* Jour. de Pharmacie, x. 30.

It is obvious, that laurin has considerable analogy with the solid fat oils, or the acids obtained when these oils are saponified.

The volatile oil of laurel berries is colourless, has an acrid and bitter taste and the smell of the laurel. At the temperature of 53°½ it is butyraceous, at 86° it melts completely. Below 53°½ it is solid, and has a dirty-white colour.

37. *Laurus* or *ocotea pichurim*. The berries of this tree, which is a native of South America, and grows near Cumana, were subjected to a chemical analysis by M. Bonastre.* He extracted from them

Volatile oil	3
Butyraceous oil	10
Stearin	22
Glutinous resin	3
Brown colouring matter	8
Starch	11
Soluble gum	12
Do. resembling tragacanth	1·2
An acid	0·4
Uncrystallizable sugar	0·8
Saline residue	1·5
Moisture	6·0
Parenchyma	20·0
	98·9

When we distil the beans of this plant with water, we obtain the volatile oil in a concrete state. Its smell is similar to that of laurel oil, or of oil of sassafras. Its taste is hot and acrid. When a little sulphuric acid is added to the water with which the beans are mixed and the mixture is distilled, we obtain the volatile oil in a liquid state, of a light yellow colour, and a more disagreeable, almost an empyreumatic odour.

38. *Momordica elaterium*. The fruit of this plant, called *wild cucumber*, is occasionally used in medicine under the name of *elaterium*. The plant is a native of the south of Europe, and is cultivated in Britain, but cannot withstand the severity of our winters. The female flowers (it is a monœcious plant) sit on the germen. This germen swells into a fruit, having the appearance of a small cucumber, of a greyish colour and covered with prickles. When fully ripe, it quits the peduncle and casts out the seed and juice with great force, and to a considerable distance through the hole in the base, where the footstalk is inserted.

For medical purposes the fruit is gathered in September, just before it is ripe. It should be sprinkled with water, each cucumber cut through longitudinally, and the clear juice which runs from it strained through a seirce. The seeds should also be scooped out and washed, and the slit cucumber also washed. After standing a

* Jour. de Pharmacie, xi. 1.

few hours, the liquid deposits a sediment, which is *elaterium*. It should be carefully dried in a warm place spread upon linen cloth. The extract from the inspissated juice is mixed in the elaterium of the shops.

Elaterium was analyzed in 1817 by Braconnot.* He found that when the expressed juice is boiled, coagulated albumen is deposited. When the liquid was evaporated, he obtained an extract composed of 40·3 parts of a peculiar bitter principle, and 34·7 of a matter insoluble in alcohol, and precipitable by infusion of nutgalls.

He obtained also 6·9 parts of nitre, 2·8 of a salt of potash, the acid of which seemed to be the malic, 7 of a salt of lime saturated with the same acid, and 8·3 of sulphate and muriate of potash.

The bitter principle is obtained by digesting the extract of elaterium, in alcohol, which leaves the nitre and the substance precipitable by infusion of nutgalls. During the evaporation of the alcoholic solution, a little more nitre is deposited. The alcoholic solution being evaporated to dryness, the residue is dissolved in water, and acetate of lead is dropt into the solution which throws down the malic acid and a portion of the matter precipitable by infusion of nutgalls. The filtered liquid is mixed with tartaric acid to throw down the oxide of lead and the potash. Being filtered again, it is evaporated to the consistence of honey. Alcohol being digested on this residue, the yellow principle is dissolved, while the tartrates are left behind. The alcoholic solution being evaporated, leaves the bitter principle still contaminated with a little nitrate and muriate of potash.

The bitter principle thus obtained, has a brown colour, and a very bitter taste. It is very soluble in alcohol, but little soluble in ether. Barytes water, alum, and the metallic salts do not occasion a precipitate when dropt into its solution. With alum and potash it gives a yellow precipitate. The protosulphate of iron gives the solution a brown colour. Infusion of nutgalls throws down a copious precipitate.

About the year 1818, Dr Paris of London, and Mr Faraday, made a set of experiments on elaterium,† from which it appears that the active principle in the fruit is a peculiar substance, to which they have given the name of *elatin*. They found that alcohol of 0·817 dissolves from the extract from the juice of the fruit 12 per cent. of matter. The alcoholic solution is green, and yields when evaporated a green residue, from which boiling water extracts a small quantity of a very bitter substance, which gives it a yellowish-brown colour. The insoluble portion is a green resin, soluble in alcohol and precipitated from this solution by water. This is the substance to which the name of *elatin* has been given.

Its colour is green, its smell disagreeable and its taste weak. One eighth of a grain of this substance is sufficient to act violently as a purgative.

* Jour. de Phys. lxxxiv. 292. † Paris' Pharmacologia (4th Edition), p. 373.

M. Clamor Marquart, gives the following process for extracting this substance, to which he has given the name of *elaterin*:—

The fruit, not yet ripe, is gathered in July, subjected to the press, and the juice evaporated to the consistence of an extract. This extract is digested in alcohol of 0·833. The alcohol is distilled off and the residue diluted with boiling water, gives, on cooling, crystals of elaterin, which cover chlorophylle. They are collected on a filter and the chlorophylle is separated by washing them with ether. Elaterin thus obtained, is crystalline, colourless, and almost insipid. When distilled, it gives off ammonia. It is insoluble in water, but easily soluble in alcohol. It is quite neutral, scarcely soluble in ether, very soluble in hot oil of turpentine, though little soluble in that oil while cold.* M. D. Morrus† had already extracted *elaterin* by a process nearly similar, but the characters of his elaterin do not exactly agree with those of the elaterin of Marquart.

In the portion of elaterium, insoluble in alcohol, Dr. Paris found

Starch	28
Extractive	26
Albumen	5
Lignin	25
Water	4
	88

39. *Myristica moschata.* The well known fruit of this tree is the *nutmeg*, so much used as an article for seasoning food. The tree is a native of the Mollucca islands. But has been nearly extirpated by the Dutch, except in Sumatra and Banda, where enough is raised to supply Europe. The covering of the nut is known by the name of *mace*. The nutmeg varies in size and figure; it is furrowed on the outside, and greyish-brown internally. Those that want white streaks are the best. From the experiments of Neumann, we learn that this substance contains two species of oil: a volatile oil, to which it owes its peculiar smell and taste, and which in his trials amounted to about $\frac{1}{32}$d part of the nut; and a solid fixed oil resembling wax, and amounting to about $\frac{1}{3}$d of the nutmeg. He detected also a quantity of gum;‡ and it is probable, from the appearance of the kernel, that it contains likewise starch. By expression, the solid oil is separated, and mixed with the volatile oil. In that state it is sold under the name of *oil of mace*.

The nutmeg has been analyzed by M. Bonastre,§ who obtained

Fat butyraceous oil	31·6
Volatile oil	6·0
Starch	2·4
Gum	1·2
Acid	0·8
Lignin	54·0
	96·0

* Jour. de Pharmacie, xxii. 665. † Ibid. xviii. 27. ‡ Neumann's Chem. p. 404.
§ Jour. de Pharm. ix. 281.

The butyraceous oil has been described in a preceding Chapter of this volume, under the name of *butter of nutmeg*.

40. *Myristica sebifera*. The fruit of this tree which is a native of Guiana, has been also examined by Bonastre, who found a considerable resemblance between it and that of the *myristica moschata*.* He extracted from it

A volatile oil
A butyraceous matter
A sebaceous crystalline matter
Gum
Parenchyma
An acid.

41. *Canabis sativa*. The seeds of this plant which produces the common *hemp*, were subjected to a chemical examination by Bucholz. The following are the results which he obtained:—

Sixteen parts of hemp-seed yielded by expression rather more than 3 parts of a yellow-coloured oil. Its taste was mild, and it possessed all the characters of the fixed oils. From the residue he procured, by digestion in water and coagulation by heat, about $3\frac{1}{2}$ parts of albumen, and not quite $\frac{1}{2}$ a part of fibrous matter. The insoluble coats and husks of the seeds weighed $6\frac{1}{8}$ parts. About $\frac{1}{4}$th of a part of a brown-coloured resin was obtained by means of alcohol, and about the same quantity of a substance to which Bucholz gives the name of *mucilaginous sugar*, and *soapy extract*, and about $1\frac{1}{2}$ part of *gummy extractive*.†

42. *Phytolacea decandra*, or *American night-shade*. The berries of this plant give a beautiful purple colour to water, of a very fugitive nature. A few drops of lime water change it to yellow; and this yellow liquid is the most delicate test of acids hitherto observed. The smallest quantity of acid restores its purple colour. Braconnot, to whom we are indebted for these observations, has shown, that it is at least four times as delicate as the infusion of litmus. Unfortunately it alters its nature in a few hours, and then loses its delicacy as a reactive. It can only be used when recently prepared.‡

43. *Menispermum cocculus* (*cocculus suberosus* of Decandolle). The berries of this shrub, which is a native of the East Indies, are about the size of a pea, and of a blackish or greenish-black colour. Under a thin covering they contain a white kernel. These berries have scarcely any smell, but they have an acrid, burning, and bitter taste. They were examined in 1811 by Boullay, who discovered in them a substance to which he gave the name of *picrotoxin*, and which has been described in a preceding Chapter of this volume. In 1833 Pelletier and Couerbe discovered in the covering of the berries two new alkalies, which they distinguished by the names of *menispermina* and *paramenispermina*. These also have been described in a preceding Chapter of this volume.

Boullay found in these berries

* Jour. de Pharmacie, xix. 186.
† Gehlen's Jour. vi. 615.
‡ Ann. de Chim. lxii. 81.

A fat oil
Tallow
A yellow extractive matter
Picrotoxin
Albumen
Lignin
Sulphates, phosphates, and muriates of potash and lime.

The ashes contained silica and peroxide of iron.

Boullay announced the presence of a peculiar acid in these berries, to which he gave the name of *menispermic acid*. But Casaseca could not find any traces of this acid, and ascertained that the tallow, of which Boullay spoke, was a mixture of oleic and margaric acids. Boullay made a new set of experiments on these berries,* and has shown that the alcoholic liquid from which the picrotoxin has been deposited, yields, when evaporated, an insipid crystalline body which reddens litmus paper, is little soluble in water, and forms with the alkalies crystallizable compounds. This is the substance which he calls *menispermic acid*. But its properties have not hitherto been farther investigated.

These berries were analyzed again, in 1833, with great care by Pelletier and Couerbe.† They obtained from it

Picrotoxin
Resin
Gum
A fat oily acid
Wax
Odorous matter
Malic acid
Mucus
Starch
Lignin
Nitrate of potash
Chloride of potassium
Sulphate of potash
Carbonate of potash } by calcination
Carbonate of lime }
Manganese
Iron.

44. *Daphne mezerium*. This plant, the common mezerion of our shrubberies, grows wild in Great Britain and other northern countries. It flowers early in spring, before the leaves appear, and bears red pulpy berries containing one round seed. There is a variety with white flowers and yellow fruit; but the qualities of both are the same. These berries are very poisonous, six of them, it is said, being sufficient to kill a calf.

The seeds of this plant, according to Celinsky,‡ contain

* Jour. de Pharmacie, xiv. 61. † Ann. de Chim. et de Phys. liv. 178.
‡ Pfaff, Syst. de Mat. Med. iii. 179.

Very acid fixed oil . . .	57·0
Mucilage	2·0
Starch	1·5
Extractive	0·5
Gluten and albumen . .	34·5
Coat	1·0
	96·5

Willert* analyzed the fleshy part of the berries and obtained

Acid bitter extractive . .	4·2
Horny matter	0·2
Flocky matter	0·2
Mucus	1·5
Starch	0·6
Residual matter . . .	10·9
Water	82·4
	100·0

45. *Daphne gnidium.* This plant grows in the south of Europe, and its berries are said to have the same poisonous qualities as those of the mezerion. Göbel informs us that they contain a peculiar acid, which he has distinguished by the name of *coccognidic acid.* It may be obtained by the following process.

Digest the seeds in boiling alcohol till every thing soluble is taken up. Distil off the alcohol, and treat the residue with water. During the evaporation of the aqueous solution, the coccognidic acid crystallizes.

It is in four-sided flat prisms, colourless, and has a peculiar, cooling, and acidulous taste. It neither precipitates lime water, nor the salts of barytes, lead, iron, or copper.

46. *Viscum album.* This plant, the common *misseltoe*, which grows abundantly in the south of England, though it is very rare in Scotland, produces small white berries. These berries must contain small seeds; for if they be rubbed, when ripe, on the smooth bark of almost any tree, plants of the misseltoe will be produced next winter.

All the parts of the misseltoe contain viscin, which may be extracted mechanically by expressing, for example, the juice of the bark or berries, and kneading the viscid liquor under water. The viscin remains attached to the fingers, in the form of a white opaque matter, which makes them stick to each other. The properties of *viscin* have been given in a preceding Chapter of this volume.

M. Henry has analyzed these berries.† According to him the viscin may be extracted by treating them repeatedly with ether. It first dissolves a mixture of green wax and viscin; but every succeeding digestion gives a purer and purer solution of viscin. When the ether is distilled off the viscin remains as a white mass.

* Pfaff, Syst. de Mat. Med. iii. 179.

† Jour. de Pharmacie, ix. 149, and x. 337.

The berries, thus exhausted by ether, yield to alchol a brown extractive matter soluble in water, which smells like viscin, and is precipitable by diacetate of lead.

The berries that have been treated with alcohol swell greatly when put into water. This liquid dissolves gum, and separates also the bassorin, which occasions the swelling of the seeds, and which is separated with difficulty from the solution of gum. The aqueous solution being evaporated, furnishes a gum similar to gum arabic, and which gives mucic acid when treated with nitric acid. But it is not precipitated, as gum arabic is, by diacetate of lead or the silicate of potash.

The misseltoe berries contain, besides lignin and salts of potash, lime, magnesia, and oxide of iron, united to vegetable acids.

47. *Coffæa Arabica.* The fruit of this tree is well known by the name of *coffee beans*, and is in general use for the manufacture of the agreeable liquor, *coffee*, so generally used, both on the continent of Europe and in this country, as an article of food. The tree is doubtless a native of Arabia; but it is extensively cultivated both in the East and West Indies and in South America, and its beans constitute a most extensive article of commerce.

We have already given the history of coffee, while treating of *caffeic acid*, in the first Division of this volume, and we have also given the properties of *caffein*, while treating of neutral bodies. It remains here merely to give an account of the constituents of coffee beans, so far as they have been ascertained.

The infusion of coffee in boiling water is of a yellowish-green colour; but the decoction, by continuing the boiling, becomes brown. It becomes turbid on cooling. The alkalies render it more brown. It strikes a black with sulphate of iron, but does not precipitate with glue. Chlorine nearly destroys the colour; but if an alkali be added the liquid becomes red. Cadet obtained a decoction with coffee which produced no effect upon vegetable blues; but other chemists describe it as changing them to red, and Hermann obtained with alcohol a solution which produced the same effect.

When water was distilled from coffee, what came over had an aromatic odour, and a few drops of a substance similar to myrtle wax swam on the surface of it; the residual liquid became milky when mixed with alcohol, and let fall a substance possessing the properties of gum.

When alcohol is digested on coffee, it acquires some colour. The solution when mixed with water becomes milky, and lets fall a whitish resinous matter. The residue being evaporated to dryness leaves a substance composed partly of extractive, and partly of the bitter principle discovered by Chenevix. From these experiments, chiefly made by Cadet, we see that coffee contains an aromatic principle, a little oil, gallic acid, mucilage, extractive, and bitter principle. It contains also, according to Cadet, sulphate of alumina, lime, muriate of potash, and a little albumen, which separates from the decoction in the form of scum. The result of Cadet's

experiments was nearly as follows. Sixty-four parts of coffee yielded

Gum	8·0
Resin	1·0
Extract and bitter principle	1·0
Gallic acid	3·5
Albumen	0·14
Lignin	43·5
Loss	6·86
	64·00

Hermann obtained from 1920 parts of Levant and Martinique coffee the following proportions respectively :—

	Levant.	Martinique.
Resin	74	68
Extractive	320	310
Gum	130	144
Lignin	1335	1386
Loss	61	12
	1920	1920

When coffee is roasted, a portion of tannin is formed in it by the action of the heat. It appears also that a new substance, having a peculiar agreeable smell, is developed; but the nature of this new principle has not yet been ascertained. It is developed also by roasting barley, beans, and a great variety of other vegetables, which are on that account occasionally employed as substitutes for coffee.

Robiquet and Boutron have shown that Martinique coffee contains about $\frac{1}{9}$th of its weight of a fixed oil which combines readily with alkalies.*

No notice is taken in these analyses, nor in the elaborate analysis of Schrader, of *caffeic acid* or *caffein*, both of which are essential constituents of coffee beans. But the facts ascertained respecting these two bodies have been already stated in a preceding part of this volume.

48. *Humulus lupilus.* The fruit of this plant, *common hops*, is employed extensively in the manufacture of beer and ale. The culture of the hop plant was introduced into the south of England, from Flanders, in 1524;† and the cones, constituting the ripe fruit, began to be used for preserving English beer towards the end of the reign of Henry VIII.‡ For many years after their introduction strong prejudices were entertained against them.

The hop plant is diœcious and climbing. The female plants only bear fruit, which has the form of solitary cones or strobiles,

* Jour. de Pharmacie, xxiii. 101.

† There is no sufficient evidence that hops were known to the ancients.

‡ Henry's Hist. of Great Britain, xii. 268, and Beckmann's Hist. of Inventions, iv. 339.

ovate and pendulous, composed of membranous scales of a pale green colour, each containing one round flattish seed of a bay-brown colour, surrounded with a sharp rim, and compressed at the top.

At the proper season, when the cones are scarcely ripe, the plants are cut about three feet from the ground, and the cones carefully picked off, one by one. Those that are too ripe or defective, are carefully separated from those that are ripe enough, and both kinds are carried to the kiln, as soon as possible after they are picked. The heat of the kiln must be nicely regulated. Many kilns have two floors, on the uppermost of which the greener hops are laid, and gradually dried before being brought to support the heat of the lower floor. Charcoal is the fuel used, other kinds of fuel injuring the flavour of the hops. They are considered as sufficiently dry when they become crisp; but they acquire some toughness and tenacity by being laid in heaps in the store-house. Five pounds of moist hops weigh only one pound when taken from the kiln. The best hops are brought to market in fine canvas bags, called *pockets*, each of which contains about $1\frac{1}{2}$ cwt. of hops. In 1830 the quantity of hops raised in the south of England was about 20,000,000 lbs.

Dr Ives' observations and experiments on the yellow powder from hops, which he called *lupulin*, and to which he ascribed the whole virtue of the plant, have been already detailed in a preceding Chapter of this volume.

MM. Payen and Chevallier made an analysis of the lupulin of Dr Ives, in 1822.* They extracted from it the following substances:—

Volatile oil	2
Diacetate of ammonia	—
Gum	—
Bimalate of lime	—
Bitter principle	12·5
Resin	52·5
Silica	4·0
Traces of fatty matter	—
Some salts	—
	71

At a later period Payen and Chevallier, in conjunction with Pelletier, resumed their examination of the lupulin of Ives.† They found it to contain 13 per cent. of the weight of the cones. But of these 13 parts there were 4 parts of foreign matter, thus reducing the true quantity of lupulin to 9 per cent. When distilled with water, it gave about 2 per cent. of its weight of a colourless volatile oil, to which hops owe their peculiar smell. This oil dissolves in considerable quantity in water.

The oil obtained by distilling the cones with water, seems to contain sulphur, for the water which distils over blackens silver. It contains also acetate of ammonia.

* Ann. de Chim. et de Phys. xx. 311. † Jour. Chim. Med. ii. 527.

If we treat lupulin with alcohol, 65 per cent. of it is dissolved. If we distil off the alcohol and add water to the residue, a resin precipitates. This resin has a reddish-yellow colour, a weak smell of hops, and a feeble aromatic taste, without any bitterness. It amounts to 52·5 per cent. of the lupulin. It is very soluble in alcohol and ether. But this last menstruum leaves bitter principle undissolved, when the resin contains any.

The aqueous solution contains the bitter principle of hops, which these chemists have distinguished by the name of *lupulite*, mixed with a little tannin and malic acid. To obtain it in a state of purity, the free acid is saturated with lime, and the liquid being evaporated to dryness, the residual matter is digested in ether, which dissolves a little resin. The undissolved portion is now treated with alcohol, which dissolves the *lupulite* and leaves the malate.

The weight of the lupulite amounts to from 8·3 to 12·5 per cent. of the lupulin.

It is sometimes nearly white, and sometimes of an orange-yellow colour. In the former case it is opaque, in the latter transparent. At the ordinary temperature of the air it is without smell, but when heated it has the smell of hops. Its taste is bitter, and similar to that of hops. It is little soluble in water, which, when boiling hot, dissolves only $\frac{1}{20}$th part of its weight of it. The solution has a pale yellow colour, and is neither acid nor alkaline. The dilute acids and alkalies have no action on it, nor is it altered by solutions of the metallic salts.

If we evaporate this solution, it becomes covered with a brownish-yellow pellicle, which melts at the parts where it touches the vessel, and falls down to the bottom in brown drops. The matter thus fused is brown and brittle when allowed to cool. Lupulite dissolves readily in alcohol, but it is almost insoluble in ether.

The same constituents were found by Payen, Chevallier, and Pelletan, in the cones of the hops, as in the lupulin of Ives, but in different proportions.

49. *Musa paradisica.* The fruit of this palm has been examined by M. Boussingault. It has a sweet and slightly astringent taste. It contains

1 Sugar
2 Gum
3 Malic acid
4 Gallic acid
5 Pectic acid
6 Albumen
7 Lignin.*

50. *Hyocyamus niger.* The seeds of this narcotic plant were analyzed by Kirshhoff, who obtained

* Jour. de Pharmacie, xxii. 385.

Fixed oil, with some resin	15·6
Extractive, with sugar	2·3
Gum, with some salts	6·2
Lignin	41·8
Albumen	5·8
Volatile and narcotic matter	28·3
	100·0*

Brandes announced the presence of an alkaloid in these seeds, which he called hyocyamin. But this discovery has not been confirmed by the experiments of Brault and Poggiale, who could find no such substance either in the seeds or leaves of the plant.†

51. *Vanilla aromatica.* The pods of this parasitical plant, which is a native of Mexico, are employed to perfume chocolate. They have also been introduced into the Materia Medica in France, and some other continental nations. They have a strong but agreeable smell, and a hot biting taste. They were analyzed by Bucholz, and found to contain

1	A brownish-yellow fixed oil	10·8
2	Soft resin, scarcely soluble in ether	2·3
3	Bitter extractive, with acetate of potash	16·8
4	Acid, bitterish harsh extractive	9·0
5	Sugar, with benzoic acid	7·3
6	Gum	11·2
7	Starch	2·8
8	Lignin	20·0
9	Mucilage extracted by potash	7·1
10	Gum extracted by ditto	5·9
11	Benzoic acid	1·1
12	Water and loss	5·7
		100·0‡

52. *Hibiscus hab-el-moschus.* The seeds of this East India plant are employed on the continent as antispasmodics. They have a size somewhat less than a pea, are kidney shaped, somewhat compressed, and have a greyish-brown colour, an agreeable smell when rubbed, somewhat similar to that of musk. Its taste is bitter and somewhat aromatic. These seeds were subjected to a chemical examination by M. Bonastre, who obtained the following substances:—

1	Parenchyma and moisture	52
2	Mucilage or gum	36
3	Albumen	5·6
4	Fluid fixed oil	
5	Solid body	
6	Odorous substance	6·4
7	Coloured resin	
		100·0§

* Berl. Jahrb. xvii. 114. † Jour. de Pharmacie, xxi. 134.
‡ Repert. ii. 253. § Jour. de Pharmacie, xx. 381.

The fixed oil has a greenish yellow colour. It is fluid at 32°; but deposits crystals in stars. Exposed to the air for a month, it concretes into plates. It forms soap with the alkalies.

The solid body is deposited when the alcoholic decoction of the seeds is allowed to cool. It is white, and has a pearly lustre. It has a sweet and agreeable taste. It dissolves readily in ether, from which, by spontaneous evaporation, it is deposited in small crystals in rays. These crystals are surrounded by a transparent substance which does not crystallize. It melts at 95°, and does not crystallize on cooling.

The *odorous body* was obtained by washing, for a second or two, the residue of different alcoholic macerations of the seeds, after strong expression. When the alcohol was left to spontaneous evaporation, the odorous matter was deposited. Its colour was light green, its consistence semifluid at the temperature of 48°, and it became less fluid when the temperature was sunk. It has a well characterized odour of musk. When left exposed to the air for some weeks its smell loses much of its intensity. M. Bonastre did not succeed in obtaining from it a volatile oil.

The resin had a blackish-brown colour, an agreeable smell and a pitchy consistence.

53. *Cardamum minus.* The seeds of this plant, examined long ago by Neumann, were subjected in 1834 to a chemical analysis, by M. J. B. Trommsdorff.* He obtained the following substances:—

1 Essential oil	4·6
2 Fixed oil	10·4
3 Salt of potash, probably malate	2·5
4 Starch	3·0
5 Azotized mucilage with phosphate of lime	1·8
6 Yellow colouring matter	0·4
7 Lignin	77·3
	100·0

The essential oil could not be obtained from the capsules, but was from the seeds themselves, by distilling them with water. It was colourless, had an agreeable odour, and a strong aromatic burning taste. Its specific gravity was 0·943. It was very soluble in alcohol, ether, the volatile and fixed oils. Concentrated acetic acid dissolved it abundantly, but it is insoluble in potash ley. It does not detonate with iodine. When long kept, it becomes yellow and viscid, and loses its peculiar taste and smell. It then detonates with iodine, and takes fire when placed in contact with concentrated nitric acid.

The fixed oil was extracted by macerating the bruised seeds in ether for eight days. The greatest part of the ether and volatile oil was distilled off. The residue was left in a warm place to spontaneous evaporation. It was then distilled with water, to get rid of all the volatile oil. The fixed oil being freed from the water had a slightly bitter taste, gave a greasy stain to paper, was very

* Annalen der Pharmacie, xi. 25.

soluble in alcohol, and was disengaged from that solution by water. It was very soluble in ether, the volatile and fixed oils. Potash dissolves it only when boiling hot, and the oil is separated unaltered by an acid. Nitric acid has little action on it when cold, but when heated gives out a deep-red colour. When heated in a platinum spoon, it burns with flame, giving out much smoke.

These characters show an analogy between this fixed oil and castor oil.

54. *Rhus coriaria*, or *sumac*. M. Trommsdorff has ascertained that the berries of this shrub, which have an acid and slightly astringent taste, contain a great deal of bimalate of lime. M. Trommsdorff recommends these berries as one of the easiest means of getting pure malic acid. The berries are macerated in boiling water, the liquid filtered and evaporated. Crystals of bimalate of lime are obtained, which are purified by a second crystallization. This salt is dissolved in water, the lime thrown down by potash, and the malic acid by acetate of lead. The malate of lead is decomposed by sulphuretted hydrogen, and the malic acid crystallized.*

55. *Lithospermum officinale*. The seeds of this plant have been long known for their remarkable hardness. And it appears from the analysis of them, by Captain Lehunt, that they contain a greater quantity of earthy than vegetable matter. He obtained

Carbonate of lime . . .	43·7
Silica	16·5
Vegetable matter, with phosphate of lime, oxide of iron, and traces of potash and manganese . .	39·8
	100·0†

56. *Melia sempervirens*. The fruit of this shrub, originally from Syria, but common in the West Indies, is a drupe, about the size of a small olive. When ripe it has a greenish-yellow colour. It contains a kernel divided into 5 compartments, and containing 5 seeds. It was considered as poisonous; but M. Ricord-Madianna has proved, by numerous trials, both on dogs and men, that not only the fruit, but every part of the plant is innocent.‡ He extracted from the fruit of this plant

Water	55·55
Chlorophylle	2·77
Resin	0·66
Sarcocollin	3·33
Mucus	0·17
Gum	5·55
Starch	3·89
Fixed oil	1·39
Lignin	25·55
Acetic acid	trace
	98·86

* Ann. der Pharmacie, x. 328. † Jameson's New Phil. Jour. for July 1832, p. 25.
‡ Jour. de Pharmacie, xix. 500.

57. *Solanum lycopersicum.* The berries of this plant, which is a native of South America, though cultivated in Europe, are known by the name of *love apples.* They are round fleshy berries, having a yellow-red colour, containing a great number of seeds, inclosed in an acid pulp. They were examined by MM. Foderé and Hecht,* who extracted from them the following substances :—

1. An acid seemingly peculiar. It is destroyed by a distilling heat. In the berries it is combined with a bitter matter, probably *solanina.*
2. A volatile oil, difficult to separate, and which evaporates with great rapidity.
3. An Extracto-resinous brown matter, of a pitchy consistency, having a strong smell, a bitter-sweet taste, soluble in water, and partly soluble in alcohol and ether.
4. An albuminous matter, which readily putrefies.
5. A little mucous sugar, detected by the smell of caromel at the commencement of combustion.
6. Sulphate of potash, a little chloride of potassium and calcium, pure potash, and probably a vegetable alkaloid, which resides much more abundantly in the leaves of the plant.

58. *Areca catechu.* The fruit of this tree, which is a native of India, is in constant use among the inhabitants of the country, along with betel and lime, as a masticatory. Of late years it has been brought from India to Europe, on account of the great quantity of tannin which it contains. It was subjected to a chemical examination, in 1822, by M. Morin,† who found it to contain

A little volatile oil
A green fixed oil
White tallow
Much tannin
Apotheme of tannin
Extractive
Gum
Lignin
Gallic acid
Acetate of ammonia
Oxalate of lime
Sulphate of potash
Chloride of potassium
Phosphate of lime
Silica, peroxide of iron.

The extractive remained in solution, after the precipitation of the aqueous solution of the fruit by acetate of lead. On evaporating the solution to dryness (after freeing it from lead) we obtain it under a solid form. Its aqueous solution is precipitated by the tannin of nutgalls, though not by that of areca nut. Yet the tannin of areca gives a black colour to salts of iron, and is precipitated by gelatine; but not by tartar emetic.

59. *Sterculia acuminata.* This is a tree which grows in the

* Jour. de Pharmacie, xviii. 106. † Ibid. viii. 449.

interior of Africa, the fruit of which, under the names of *goula*, *gola*, and *cola*, is used as a masticatory by the negroes of Benin, Congo, and the banks of the Niger, and is highly esteemed by them. The tree yielding it was first described by M. Palisot Beauvois, in his *Flora of Owore and Benin*. The fruit is a nut composed of five capsules. Each seed of the form of a chesnut, is fleshy, of a violet-red colour, while externally its colour is bluish-red. No analysis of it, so far as I am aware, has been made; but I am induced to mention it here to draw to it the attention of chemists.*

60. *Phœnix datilyfera*. The fruit of this palm tree, well known by the name of *dates*, constitute an important article of food to the inhabitants of those countries where it is indigenous. Its taste is sweet, and it contains a good deal of sugar. This is the reason why a vinous spirit, and even alcohol may be obtained from it. This fruit was subjected to a chemical examination by M. Bonastre,† who extracted from it

Mucilage
Gum
Albumen
Incrystallizable sugar
Crystallizable sugar, same as common sugar
Parenchyma.

61. *Jatropa curcas*. The seeds of this tree, which is a native of the Moluccas, and called by the French *pignon d'Inde*, have been subjected to a chemical analysis by M. Soubeiran.‡ The seeds are oval and shining, and contain a white oily kernel. Their taste is acrid and nauseous, and when taken internally they excite vomiting, and act as a cathartic. Soubeiran extracted from these seeds

1 A fixed oil
2 Gluten
3 Gum
4 Sugar
5 Malic acid
6 A little fatty matter
7 Some salts
8 A fixed acrid substance approaching resin.

The oil obtained by expression is limpid and colourless, has no smell, and congeals when cooled a little below 32°. Its taste is acrid, and it acts as an emetic and purgative, because it contains a small quantity of the acrid matter of the seeds. This matter may be separated by agitating the oil with cold alcohol, which dissolves it without uniting with any notable quantity of the oil. For this oil, unlike that of castor and croton oils, is insoluble in cold, and very little soluble in boiling alcohol.

The *acrid substance* is easily separated from the triturated seeds, by treating them with alcohol of the temperature 95°. The alcohol expressed is filtered and distilled. There remains a yellow-

* See Virey, Jour. de Pharmacie, xviii. 702. † Ibid. 724.
‡ Jour. de Pharmacie, xv. 503.

coloured liquid, on which swims an insoluble matter. The liquid contains sugar and a little malic acid. The insoluble matter is washed in water. It is dissolved in alcohol, and cautiously saturated with dilute barytes water. It is filtered, to separate the salts of barytes formed, and a little oil. It is evaporated to dryness. The residue is the acrid matter. It has a yellow colour, and is still of a soft consistence. It has no smell, but a very acrid taste, which continues long in the mouth. It melts a little above 212°, and concretes again on cooling. It is insoluble in water, but soluble in alcohol in all proportions. The alcoholic solution has no action on vegetable colours. Water renders it milky. It dissolves in sulphuric and acetic ethers. The dilute acids have no action on it. The alkalies dissolve it.

62. *Croton tiglium.* The seeds of this tree, which furnish the croton oil, were analyzed by M. Brandes, and found to contain

A volatile oil
Crotonic acid
An alkaloid
Colouring matter
Stearin
Wax
A subresin
Inulin
Gum
Gluten
Tragacanth
Albumen
Do. coagulated
Starch
Phosphate of magnesia.*

63. *Tanghinia Madagascariensis.* The fruit of this tree, which is a native of Madagascar, has been long known in that island for its poisonous qualities. It was subjected, in 1823, to a chemical analysis by MM. O. Henry and Olivier.† They extracted, by compression, a fixed oil, which becomes solid at 50°. When the residue is digested in ether, a peculiar crystallized matter is extracted, to which they have given the name of *tanghicin*. It crystallizes during the evaporation of the ether.

Tanghicin is soluble in alcohol of 0·815, and crystallizes during the evaporation of the solution in transparent plates, which effloresce in the air and become opaque. It is insoluble in water. Its taste is at first bitter, then extremely acrid, and it leaves a sensation of astringency in the throat. It melts when slightly heated, and in that state resembles yellow resin. It contains no azote. It is a neutral substance, and seems neither to combine with acids nor alkalies. When taken into the stomach, it acts as a powerful poison.

When the portion of the fruit freed from the tanghicin by ether

* Jour. de Pharmacie, xi. 144. † Ibid. x. 49.

is treated with alcohol, a brown viscid substance is dissolved, which contains a free acid. This substance contains no azote. Acids give it a green, and alkalies a brown colour.

Besides these substances, tanghicin contains much albumen, a little gum, and traces of iron and lime.

64. *Cassia acutifolia.* The fruit of this plant, the *senna* of the shops, has been examined chemically by M. Feneulle.* He found it to contain

1 Cathartina
2 A colouring matter
3 A little albumen
4 Much mucilage
5 A fixed oil
6 A volatile oil
7 Malic acid
8 Malates of potash and lime
9 Chloride of potassium, sulphates, subphosphates, and carbonates of potash and lime
10 Silica
11 Lignin.

The cathartina is somewhat less in proportion, in the follicles or fruits of the cassia than in the leaves.

65. *Bertholletia excelsa.* The fruits of the tree, which is a native of Brazil, constitute triangular nuts called Juvias. They consist each of a thin woody shell enclosing a kernel. They were subjected to a chemical analysis by M. Morin.† From the shell he extracted

1 Gallic acid
2 Tannin
3 Incrystallizable sugar
4 Acetate of potash
5 Gum
6 Several mineral salts.

From the kernel were obtained

1 A fixed oil, composed of elain and stearin
2 A great quantity of albumen
3 Liquid sugar
4 Gum
5 Lignin.

This shows a striking analogy with the constituents of sweet almonds.

66. *Syringa communis.* A very elaborate analysis of the fruit of this shrub, the common *lilac*, has been made by MM. Petroz and Robinet.‡ They obtained

1 Resin
2 Sugar
3 A substance which throws down iron grey

* Jour. de Pharmacie, x. 58. † Ibid. 61. ‡ Ibid. 139.

4 A bitter principle
5 An insoluble jelly
6 Malic acid
7 Bimalate of lime
8 Nitrate of potash
9 Some mineral salts.

The resin is much less easily dissolved in alcohol than common resins. They consider it as chlorophylle altered by vegetation.

The sugar differed from common sugar in the form of its crystals, flat four-sided prisms, with an inclined base.

The substance which precipitated iron grey, when dried, had a brown colour and great lustre. None of its other characters were noticed.

The bitter principle had the property of changing solutions of protoxide of iron to green, but it produced no effect upon solution of the peroxide. It dissolved readily in acetic ether, but very imperfectly in sulphuric ether. It was soluble in alcohol and water, and the aqueous solution precipitated the nitrate of mercury. It has no action on acetate of lead, but throws down subacetate yellowish-white.

The jelly was semitransparent, insipid, inodorous, and almost colourless. It was insoluble in water, alcohol, ether, oils, and ammonia. Dilute acetic, nitric, and phosphoric acids dissolve very little of it. Nitric acid, when its action is long continued, converts it into oxalic acid. Its solution is precipitated by lime. It burns like gum.

67. *Hura crepitans.* The seeds of this tree, which is a native of India, but cultivated in America and the West Indies, are employed by the natives as a purgative. They act with great violence in general. The leaves give out a milky juice like the euphorbia.

M. Bonastre subjected these seeds to a chemical analysis,* and obtained

1 A fixed oil, slightly acidified	51·11
2 Stearin	4·45
3 Parenchyma . . .	38·89
4 Gum	1·11
5 Moisture	2·22
6 Saline residue . . .	2·22
	100

We do not see here the substance which possesses cathartic effects, unless we ascribe them to the fixed oil.

* Jour. de Pharmacie, x. 479.

CHAPTER XIII.

OF FERNS.

Very few chemical investigations of this beautiful and numerous tribe of plants have yet been made. One or two of them have been employed in medicine, and upon these a few imperfect analyses have been sketched out, which I shall notice in this place.

1. *Aspidium filex mas.* This fern is the *polypodium filex mas* of Linnæus. The root of it has a bitter taste, and was employed as a medicine by the ancients; for it is considered by botanists as the θηλυπτερις of Dioscorides,* the roots of which, he says, possess the property of expelling the tape-worm. Though recommended by some modern practitioners, it was little used till the French government, in 1775, purchased Madame Noufer's secret remedy for the tape-worm. She was the widow of a Swiss surgeon, and her remedy had acquired great celebrity. It was the powdered root of this plant.

The dried root is nearly without smell. Its taste is at first sweetish, then slightly bitter and astringent, and it is mucilaginous when chewed. It varies much in its properties, according to the season of the year in which it is taken up, and becomes inert if kept above two years. The roots should be dug up in summer, when they have a greenish colour and a nauseous smell, and do not change when they are dried in the air.

They were analyzed by M. Morin, in 1824.† According to him, they owe their anthelmintic property to an oily substance capable of being saponified. It has a nauseous odour, similar to that of the roots. Its taste is very disagreeable. It is heavier than water, when burnt emits a thick smoke, and it may be distilled over with water. The roots contain, besides gallic and acetic acids, uncrystallizable sugar, tannin, starch, a gelatinous matter insoluble in water and alcohol (bassorin?), lignin, and some salts which are found in the ashes.

The oily matter may be obtained by the following process:—Digest the pounded root in ether, till that liquid will dissolve nothing more. Distil off the greatest part of the ether, and evaporate the last portions of the solution in an open vessel. The oil remains. It reddens vegetable blues, yields a little volatile oil when distilled with water, and when left at rest deposits stearin. It is partially soluble in alcohol, and the solution deposits crystals of stearin. To

* Lib. iv. cap. 186. † Ann. de Chim. et de Phys. xxvi. 219.

this oil M. Peschier ascribes the anthelmintic properties of the fern root.*

2. *Aspidium coreacium.* This fern, which is a native of Peru, is called in that country *calaguala*. The root of it was introduced into medicine as a cure for pleurisy, but it was not found to possess the properties ascribed to it. Vauquelin, who subjected it to analysis, found it a very complex substance, and separated from it no fewer than the following substances:—

Lignin	Colouring matter
Gum	Malic acid?
Resin	Muriate of potash
Sugar	Lime
Starch	Silica.

Alcohol dissolves the resin and sugar. By evaporating the solution to dryness, and treating the residue with water, the sugar is separated and the resin left. This resin has a reddish-brown colour, and a bitter and acrid taste. It dissolves in alkalies, communicating a brown colour and a bitter taste, and is again separated by acids. Vauquelin suspects that this principle is the constituent of the root, both of this plant and of the other filices which possess vermifuge properties. Water dissolved the gum and the muriate of potash, which were obtained by evaporation. Diluted nitric acid dissolved the starch and the colouring matter, and let fall the former when mixed with four times its bulk of alcohol. The woody fibre remained, which, when incinerated, left carbonate of lime, muriate of potash, and a little silica. As the decoction reddened vegetable blues, it is possible that the lime was in combination with malic acid.†

3. *Aspidium fragrans.* This fern grows on the high rocks round the lake Baikal. It is called by the natives *serlik*, and is used by them as a substitute for tea. It is said to resemble very closely common green tea in its flavour.‡

4. *Polypodium vulgare.* The root of this fern, formerly used in medicine, was examined by M. Desfosses. He found it to contain a sweet-tasted substance, possessing the properties of *sarcocollin*, mannite, incrystallizable sugar, starch, albumen, malic acid, lime, magnesia, and oxide of iron.§ Viscin had been found in this root by M. Planche, in 1812.‖

5. Several of the equisetums have been subjected to a chemical analysis by M. Braconnot.¶ They do not, strictly speaking, belong to the tribe of *filices*. I shall, notwithstanding, place them here, in order to avoid too many subdivisions.

Equisetum fluviatile, or *river-horse tail.* This plant, which is so common in Great Britain, was found by Braconnot to contain

* Jour. de Pharmacie, xv. 292.
† Vauquelin, Ann. de Chim. lv. 22.
‡ Ann. der Pharmacie, ii. 355.
§ Jour. de Pharmacie, xiv. 276.
‖ Jour. de Pharmacie, xiv. 336.
¶ Ann. de Chim. et de Phys. xxxix. 1.

1	Water	81·33
2	Lignin	5·30
3	Silica	4·32
4	Pectic acid	2·26
5	Sulphate of lime	1·22
6	Equisetate of magnesia	1·10
7	Sulphate of potash	1·02
8	Extractive, insoluble in alcohol	1·00
9	Chloride of potassium	0·98
10	Saccharine matter soluble in alcohol	0·86
11	Phosphate of lime, with a little iron	0·20
12	Lime	0·16
13	Acetate of magnesia	0·14
14	Fatty matter, with chlorophylle	0·08
15	Animal matter, reddened by muriatic acid	0·02
16	Phosphate of potash	0·01
17	Oxalate of lime	traces
18	Equisetate of lime	
19	Equisetate of potash	
20	Wax	
21	Muriate of magnesia?	
		100·00

The equisetic acid, discovered by Braconnot in this equisetum, has been described in a preceding Chapter of this volume.

Equisetum hyemale. This equisetum is also a native of Britain, and is much employed in polishing, under the name of *Dutch rushes.* Braconnot examined the ashes of this species, and of three other species of the same genus. The following table exhibits the quantity of these ashes, and the constituents found in them:—

	Constituents.								
	Ashes from 100 parts of the plant.	Silica.	Sulphate of lime.	Sulphate of potash.	Chloride of potassium.	Carbonate of lime.	Magnesia.	Phosphate of lime, ferruginous.	Potash.
Equisetum fluviatile	23·61	12	3·39	2·83	2·72	1·46	0·66	0·55	0
Equisetum hyemale	11·81	8·75	0	0·33	0·28	0·93	0	0·80	0·72
Equisetum arvense	13·84	6·38	0	0·37	0·22	5·51	0·46	not weighed	0·30
Equisetum limosum	15·50	6·50	3·3	2·20	1·20	1·50	0·30	ditto	trace

CHAPTER XIV.

OF LICHENS.

The lichens are a class of plants which differ almost in every respect from other vegetables. Many of them have not the smallest appearance of plants, but form hard crusts, which cover rocks, wood, trees, &c.; others have the form of leaves or of branches, but nothing resembling flowers is visible. It was to Tournefort and Micheli that Botany is indebted for first fixing the word *lichen*, formerly vague and ill defined, to a peculiar set of plants. Afterwards Linnæus placed them among the algæ, and described 81 species. Since that time a great variety of botanical writers have devoted considerable attention to them, particularly in ascertaining and describing their parts of fructification, and the various changes which they undergo in the different periods of their vegetation; but few only have attempted to analyze them, or to point out the useful purposes to which they may be applied. Willemet has given us an historical account of 41 species of lichens, and detailed their medical and economical uses with considerable accuracy. Amoreux, in a dissertation on the subject, has given us still more copious details, and has published likewise a brief chemical analysis of some of the most remarkable lichens. Hoffmann, who had previously distinguished himself by his botanical arrangement of the lichens, published an account of their chemical and economical properties in 1787, and has given us the chemical analysis of several, made by Georgi with considerable care. Westring turned his attention particularly to the uses of the lichens in dyeing; and in seven dissertations, published successively in the *Stockholm Transactions* from 1792 to 1797, has examined almost all the lichens of the north, and described the colours which each of them is capable of yielding, and the manner of obtaining it. It is to these writers, and to Georgi, that we are indebted for the few facts known respecting the composition and chemical properties of the lichens.

The lichens are found in all countries and climates, and are very numerous; considerably more than two hundred species have been described by botanists as natives of Britain.

From the experiments of Georgi, professor of Chemistry in Petersburgh, we learn that the *ramalina farinacea*, *cetraria glauca*, *placodium physodes* form with water a mucilage which yields, when evaporated, a gum as transparent and tasteless as gum arabic. Lichen pulmonarius yields likewise a gum, but its taste is somewhat bitter. The gum yielded by these lichens amounted to $\frac{1}{3}$th of their weight. When treated with alcohol, the liquid acquires a green colour and a bitter taste.* Amoreux, who repeated these experi-

* See the experiments of Georgi, as quoted by Amoreux, in his Researches et Experiences sur les divers Lichens, p. 94.

ments, obtained from the *sticta pulmonaria*, a reddish gum, much less transparent than gum arabic. This lichen gave a yellow colour to alcohol. Probably he had examined a different species from that tried by Georgi, or if not, the lichens must have been of very different ages.

Amoreux found, that when the *evernia prunastri* was steeped in water, its branches became transparent like animal membrane, and adhered strongly to paper. In this state it is insipid, but as friable as celery. He obtained abundance of gum from the *cetraria Islandica*, and from all the broad-leaved lichens tried. He succeeded in extracting gum from the *ramalina fraxinea*, *peltidea canina*, and *lichen caperatus* of Linnæus. This last gave a lemon-yellow colour to ammonia.*

Georgi found that when *parmelia physodes*, *usnea plicata*, *ramalina farinacea*, and *sticta pulmonaria* were boiled in water, they yielded a yellowish mucilage nearly insipid, and that the lichens thus treated might be eaten with salt. They all yielded a portion of resin to alcohol, but it did not give a taste to the water in which they were boiled. When incinerated, these lichens yielded a little potash, lime, and silica, but no sulphuric or muriatic salt. When distilled, they yielded an acidulous water, and a yellow or blackish oil which sunk in water.

Such are the imperfect experiments hitherto made on the constituents of a few of the lichens. One of them, however, the *cetraria Islandica*, or Iceland moss, has been subjected to a rigorous and curious analysis by Berzelius. He obtained from 100 parts of this lichen the following constituents :—

Syrup	3·6
Bitartrate of potash with some tartrate of lime, and phosphate of lime	1·9
Bitter principle	3·0
Green wax	1·6
Gum	3·7
Extractive colouring matter .	7·0
Starch	44·6
Starchy insoluble matter . .	36·6
	102·0†

Berzelius afterwards examined the *usnea plicata*, *usnea barbata*, *ramalina fastigiata*, and the *ramalina fraxinea*. He found them all characterized by the presence of a species of starch which possesses several peculiar properties.‡

I shall now mention such of the lichens as are most remarkable for the colouring matters which they yield.

1. *Roccella tinctoria*. This lichen, which grew abundantly in the Canary islands, but which is found also on the south coasts of England

* See the experiments of Georgi, as quoted by Amoreux, in his Researches et Experiences sur les divers Lichens, p. 95.

† Ann. de Chim. xc. 277.

‡ Afhandlingar, iii. 381.

and France, yields the dyestuff called *archil*, of which an account has been given in a preceding Chapter of this volume.

2. *Lecanora parella.* From this lichen, which grows abundantly in the mountains of Auvergne, and other parts of France, and which is common also in Britain, the pigment called *archil of Auvergne* is prepared. The process is pretty much the same as that by which the lichen roccella is prepared, and the pigment is distinguished by the same name, and applied to the same use, but is not considered as so valuable. It is obvious that the colouring matter of each is analogous.

3. *Pertusaria communis.* Treated with lime and sal ammoniac, it yielded a brown colouring matter to Westring.

4. *Lecanora ventuosa.* This lichen dyed wool of a brown colour which resisted the action of alkalies.

5. *Lecanora hæmatomma* yielded a wax-yellow colour.

6. *Isidium corralinum.* This lichen was found by Westring to abound in colouring matter. By simple infusion in water, with a little common salt, it dyed wool yellow. Without addition, it gives a deep-brown of considerable permanence. It yielded the same colour when treated with sal ammoniac and lime.

7. *Isidium Westringii* yielded a fine orange, which was brightened by muriate of cobalt.

8. *Lecanora tartarea* yielded a fine brown.

9. *Lichen centrifugus*, with fixed alkalies, yielded a fine wax-yellow; with water, a brown; with common salt and nitre, an orange.

10. *Parmelia saxatilis.* This lichen, with soda, yields a yellow; with lime and sal ammoniac, a nankeen; and with muriate of soda and nitre, an orange.

11. *Parmelia physodes*, by the same reagents, yields various shades of yellow and brown; *lichen juniperinus*, yellow and brown; *lichen tenellus*, yellow, olive, and reddish-brown; *lichen furfuraceus*, yellow and brown. The same colours were obtained from a considerable number of leafy lichens.

Solorina crocea, with lime and sal ammoniac, gave out a red colour. Westring obtained several colours from other lichens; and by mixing several of them together, he varied the shade, and produced a new set of colours, differing both in their intensity and fixity. But for the particulars of his numerous experiments, the reader is referred to his dissertations on the subject.*

12. *Parmelia parietina.* This lichen, which, during the last French war, when the continent was nearly deprived of colonial produce, was recommended by Dr Sande as an excellent substitute for cinchona bark, has been subjected to a chemical analysis by M. Herberger.† He obtained

* The first has been translated into French, and printed in vols. xv. and xvii. of the Annales de Chimie. The others are inserted in Crell's Annals for 1796, 1797, and 1799.

† Jour. de Pharm. xx. 536.

Wax	1
Stearin crystals	0·5
Yellow colouring matter	3·5
Red colouring matter	0·5
Gliadine	5·2
Chlorophylle	3·5
Bitter principle, &c.	2·5
Soft resin	3·5
Gum with starch	9·0
Extractive	2·0
Ditto, dissolved by caustic potash	15·0
Lignin	46·0
Volatile oil	trace
Water	5·0
	97·2

The *yellow colouring matter* is in small yellow crystalline grains or plates, which acquired, when pulverized, a golden yellow colour. It is soluble in the volatile oils, and very soluble in alcohol and ether; but it is insoluble in water. Ammonia and the fixed alkaline carbonates dissolve it partially. The addition of caustic potash gives it a red colour; and yellow lakes are obtained by adding acetate of lead or protochloride of tin.

The alcoholic solution of this matter is coloured carmine red by caustic potash, aurora red by ammonia and the fixed alkaline carbonates. These last occasion a precipitate of yellow resin. Dilute sulphuric acid, concentrated acetic and muriatic acids, nitric acid, acetate of lead and protochloride of tin, produce the same effect. When heated in a glass tube the yellow colouring matter gives out vapours not ammoniacal, at first yellow, and then red, which condense first in drops, and then adhere to the tube in a yellow powder or yellow crystals. Finally, an empyreumatic oil is disengaged, and charcoal remains.

The *red colouring matter* was in very small red crystalline grains, having a carmine red colour. Soluble in alcohol, ether, volatile oils and hot water; but not in cold water. The alkalies and concentrated sulphuric acid deepen its colour. Dilute sulphuric acid, acetic acid, muriatic and nitric acids change its colour to yellow.

Braconnot has ascertained that many of the lichens contain a great deal of oxalate of lime. He extracted it in abundance from *variolaria communis; pertusaria communis; urceolaria scruposa; isidium corralinum; patellaria tartarea, ventosa rubra, hematomma; vœomyces ericetorum; squammaria lentigera, placodium radiosum, ochroleucum; psora candida.* And he has shown that it may be extracted by mixing the powdered lichen with about a third of its weight of concentrated sulphuric acid, diluting the mixture with water, and boiling it about half an hour. Then filtering and evaporating very cautiously, the oxalic acid crystallizes.*

* Ann. de Chim. et de Phys. xxviii. 320.

CHAPTER XV.

OF MUSHROOMS.

The mushrooms are a class of plants proverbial for the rapidity of their growth and their speedy decay. When they putrefy, they give out an extremely unpleasant odour, and appear to approach animal matter much more closely than other vegetable substances. They attracted the attention of M. Vauquelin and M. Braconnot, to whom we are indebted for the analysis of no fewer than 17 species of this hitherto neglected tribe of vegetables. Braconnot has distinguished the insoluble spongy portion which characterizes the mushrooms by the name of *fungin*, and under that name it has been described in a preceding Chapter. It approaches lignin in its properties; but seems to be sufficiently distinguished from it by various characters, particularly by constituting a nourishing article of food, and by being much less soluble in alkaline leys. Braconnot likewise ascertained the existence of two new acids in mushrooms. One of these has been described in a former part of this work under the name of *boletic acid*. The other, which appears to constitute a very general ingredient in mushrooms, he has on that account distinguished by the name of *fungic acid*.*

The following are the different species of mushroom hitherto subjected to analysis.

1. *Agaricus campestris*. This argaric, which is a common article of food, was analyzed by M. Vauquelin, who found in it the following substances :—

(1.) Adipocire. This substance was obtained by boiling in alcohol the matter that remained after the juice of the agaric was pressed out. The alcohol on cooling deposited the adipocire in flocks. It has a brownish-white colour, a fatty feel like that of spermaceti, melts when heated, and gives off a white vapour, having the odour of fat

(2.) An oily or fatty matter

(3.) Vegetable albumen

(4.) The sugar of mushrooms

(5.) An animal matter soluble in water and alcohol. When heated it gives out the smell of roasting meat. Similar to the substance called *osmazome*

(6.) An animal substance insoluble in alcohol

(7.) Fungin

(8.) Acetate of potash.†

* The name is unhappy, because, according to the received principle of naming acids, it indicates that the acid so named is a compound of *fungin* and *oxygen*; an opinion so far from being established that it has not even been advanced.

† Ann. de Chim. lxxxv. 7.

2. *Agaricus volvaceus.* This agaric, according to the analysis of Braconnot, contains the following constituents:—

(1.) Much water
(2.) Fungin
(3.) Gelatin
(4.) Vegetable albumen
(5.) A great quantity of phosphate of potash
(6.) Acetate of potash
(7.) Sugar of mushrooms
(8.) A fluid brown oil
(9.) Adipocire
(10.) Wax
(11.) A very fugaceous deleterious matter
(12.) An uncombined acid, suspected to be the acetic
(13.) Benzoic acid
(14.) Muriate of potash.*

3. *Agaricus acris*, or *piperatus.* This agaricus was examined by Dr Lister in 1672.† He obtained from it a milky juice with taste hotter than pepper, not discoloured by exposure to the air, nor by the blade of a knife. It speedily coagulated when kept in a glass vessel; but did not lose its hot taste. Trommsdorf made some experiments on it, and extracted from it a peculiar acrid matter and vegetable albumen. When distilled it yielded a considerable quantity of carbonate of ammonia.‡ Braconnot subjected it to an elaborate analysis, and extracted from it the following substances:—

Water
Fungin
Vegetable albumen
Gelatin
Much adipocire
Acetate of potash
Sugar of mushrooms
Phosphate of potash
A peculiar vegetable acid united to potash
An oily matter
A very acrid and fugaceous matter
Muriate of potash.§

4. *Agaricus stypticus.* Twenty parts of this agaric, analyzed by Braconnot, yielded

Fungin	16·7
Resin, Adipocire	1·8
Unknown gelatinous substance, Combustible acid united to potash, A fugaceous acrid principle	1·5
	20·0‖

* Ann. de Chim. lxxix. 276. † Phil. Trans. vii. 5116.
‡ Ann. de Chim. xxii. 220. § Ibid. lxxix. 285. ‖ Ibid. lxxxvii. 260.

5. *Agaricus bulbosus.* Vauquelin subjected this agaric to some experiments, and extracted from it the following substances :—

An animal matter insoluble in alcohol
Osmazome
A fatty soft mater, of a yellow colour and acrid taste
An acid salt, which is not a phosphate.

The skeleton of the agaric when distilled yielded an acid.*

6. *Agaricus theogalus.* Vauquelin extracted from this agaric,

Sugar of mushrooms
A fatty matter of a bitter and acrid taste
An animal matter insoluble in alcohol
Osmazome
A salt with a vegetable acid.†

7. *Agaricus muscarius.* This agaric was examined by Vauquelin, who extracted from it,

The two animal matters contained in the last agaric
A fatty matter
Muriate, phosphate, and sulphate of potash.

The skeleton both of this and the preceding species yielded an acid when distilled.‡

8. *Boletus juglandis.* Braconnot subjected this boletus to an elaborate and ingenious analysis. He found 1260 parts of it composed of the following constituents :—

Water	1118·3
Fungin	95·68
Animal matter insoluble in alcohol	18
Osmazome	12
Vegetable albumen . . .	7·2
Fungate of potash . . .	6
Adipocire	1·2
An oily matter . . .	1·12
Sugar of mushrooms . .	0·5
Phosphate of potash . .	trace
	1260·0§

9. *Boletus viscidus.* Braconnot found this boletus composed almost entirely of animal mucus, which acquires cohesion when heated, and becomes in part insoluble in water.‖

10. *Boletus pseudo-igniarius.* A large boletus of this species was subjected to an elaborate analysis by Braconnot, who extracted from it the following substances :—

Water
Fungin
A sweet-tasted mucilaginous matter
Boletate of potash
A yellow fatty matter

* Ann. de Chim. lxxxv. 23. † Ibid. p. 24. ‡ Ibid.
§ Ibid. lxxxvii. 237. ‖ Ibid. lxxix. 302.

Vegetable albumen
Phosphate of potash in small quantity
Acetate of potash
Fungic acid in a state of combination.*

11. *Boletus laricis.* This plant, in a dry state, is used on the continent as a medicine, and sold under the name of *agaric.* It has been examined by Bouillon La Grange.†

It is in pieces which are white, light, and friable. The outer skin is leathery and dark-coloured. Its taste is at first sweetish, but it leaves a bitter and acrid impression in the mouth. When steeped in water, it communicates a yellowish colour and a sweetish taste to the liquid. The infusion reddens vegetable blues; and holds in solution sulphate of potash, sulphate of lime, and muriate of potash.

When this substance is boiled in water, the liquid acquires a gelatinous form as it cools. Evaporated to dryness, and treated with lime, the odour of ammonia becomes perceptible. Alcohol, boiled upon the boletus, acquires a red colour; and when mixed with water, lets fall a copious precipitate, which exhibits the properties of a resin. This resin has a yellow colour, is brittle, semi-transparent, and has a sour and bitter taste. When treated with lime, and the solution afterwards decomposed with muriatic acid, a quantity of benzoic acid is obtained from it. From these experiments it is evident that this substance contains resin, benzoic acid, different salts, some extractive, and some animal matter, to which the gelatinous form of the decoction must be ascribed.

Sulphuric acid dissolves and rapidly chars the boletus. Nitric acid acts with energy; nitrous acid acts with energy; nitrous gas is disengaged, and the boletus becomes brown. By continuing the action of the acid, crystals of oxalic acid are obtained; malic acid is likewise formed, together with some resin, and a substance which approaches the nature of wax in its properties. The fixed alkalies give it a red colour, render it gelatinous, and a great quantity of ammonia is disengaged.‡

Boletus igniarius. This boletus is not uncommon in this country on the trunks of trees. A variety of it is used in Germany and some other countries as *tinder.* It is prepared for this purpose by boiling it in a solution of saltpetre, beating it till it becomes sufficiently soft, and then boiling it a second time in the same solution. In 1750 it was recommended by Brossard, a French surgeon, as an excellent styptic; and various trials were made with it, both in France and Britain. It has been subjected to a chemical examination by Bouillon La Grange.§

When boiled in water the liquid acquires a deep-brown colour and a slightly astringent taste. It holds in solution sulphate of lime and muriate of potash. When evaporated to dryness, it leaves a brown-coloured extract, which attracts moisture from the atmosphere. This substance, when incinerated, left a white ash, con-

* Ann. de Chim. lxxx. 272. † Ibid. li. 76.
‡ Bouillon La Grange, Ann. de Chim. li. 76. § Ann. de Chim. liv. 92.

taining a considerable portion of potash; and when dissolved in water, exhibited, by reagents, the presence of lime, and of muriatic and sulphuric acids. The residual portion of the boletus, being calcined, was found to contain phosphates of lime, and magnesia, and some iron.

Alcohol has scarcely any action on this boletus: but when assisted by heat, it dissolves a small portion of resin. Nitric acid dissolves it readily; malic and oxalic acids are formed, and probably also a portion of bitter principle, while carbonic acid and nitrous gas are disengaged. Alkaline leys dissolve it with difficulty; forming, however, a soapy liquid, and separating a small portion of ammonia. From these experiments, we learn that this boletus differs in many respects from the preceding. It contains much less resin, and a much smaller proportion of animal matter, and yields no traces of benzoic acid.*

13. *Hydnum repandum.* This hydnum is not uncommon in the woods. It has a yellow colour. Braconnot subjected it to analysis, and extracted from it the following substances:—

Water
Fungin
Gelatin in small quantity
Sugar of mushrooms in considerable quantity
Much acetate of potash
Fungate of potash
A little phosphate of potash
Another vegetable alkali united to potash.
An oil
Adipocire
A very fugaceous acrid matter
Muriate of potash.†

14. *Hydnum hibridum.* This hydnum has a blackish-brown colour, has not an acrid taste, and when distilled yields no ammonia, but leaves a very alkaline ash. Its constituents, according to Braconnot, are

Water	Phosphate of potash
Fungin	Fungate of potash
Gelatin	Adipocire
Sugar of mushrooms	A brown oil
Vegetable albumen	A colouring matter
Acetate of potash	Muriate of potash.‡

15. *Merulius*, or *agaricus cantharellus.* This substance has a yellow colour and an agreeable odour. When taken into the mouth its taste is at first acrid; but soon becomes exceedingly agreeable. It is very much used as an article of food. According to the analysis of Braconnot, its constituents are

Water
Fungin
Gelatin
A considerable proportion of sugar of mushrooms

* Bouillon La Grange, Ann. de Chim. liv. 92. † Ann. de Chim. lxxix. 291.
‡ Ibid. p. 297.

Acetate of potash
Phosphate of potash
Fungate of potash
Oil
Adipocire
An acrid matter destroyed by heat
An uncombined acid similar to the acetic.*

16. *Phallus impudicus.* This fungus, well known in consequence of the intolerable odour which it exhales, was found by Braconnot to contain the following constituents:—

Water
Fungin, much animalized
Albumen
Animal matter
Mucus
Superacetate of potash
A little superacetate of ammonia
Adipocire
An oily matter
Sugar of mushrooms
A little phosphate of potash
A combustible acid united to potash.†

17. *Peziza nigra*, or *lycoperdon truncatum.* This fungus is common upon the bark of oaks soon after they have been cut down. Its surface has a black colour, while the fleshy part is gelatinous, semi-transparent, and elastic. 400 parts of it analyzed by Braconnot, yielded the following constituents:—

Water	376·0
Cerasin	18·4
Gum	3·6
Fungic acid chiefly free . .	8·0
Sugar of mushrooms . .	0·4
Matter soluble in alcohol very little animalized	0·4
Fatty matter rendered purple by potash	4
Potash and lime . . .	trace
	407·2‡

18. *Lycoperdon tuber*, or *tuber cibarium; truffles.* This is a globular fungus found 4 or 5 inches under ground, in woody places, and is considered as one of the best of the eatable mushrooms. Bouillon La Grange has subjected it to a chemical analysis.§ It was attempted nearly in the manner formerly described for ascertaining the constituents of the different species of corn.

It was grated down small, and then washed with water upon a searce till the liquid ceased to carry off anything. A blackish fibrous matter remained upon the searce. The liquid let fall a brown-coloured matter when left at rest. The liquid produced no effect upon vegetable blues. The brown deposit does not resemble starch in its properties.

* Ann. de Chim. lxxix. 300. † Ibid. lxxx. 291. ‡ Ibid. lxxxvii. 253.
§ Ibid. xlvi. 197.

Water produces but little effect upon truffles. Warm water, however, dissolves a portion, which possesses the characters of albumen.

When the plant was treated with nitric acid, a solution was accomplished; nitrous gas, carbonic acid, and azotic gas were disengaged; and the solution, by distillation, yielded a liquor containing prussic acid. The residual liquid yielded bitter principle, an oily matter, and small crystals, which Bouillon La Grange considered as a combination of oxalic acid and bitter principle. He suspected also the presence of malic acid.

Alcohol dissolves a small portion of brownish bitter matter, which acquires the properties of resin by exposure to the atmosphere.

When truffles are left in the state of a paste with water, they acquire the smell of cheese. When mixed with sugar and water they undergo fermentation, carbonic acid is disengaged, and alcohol formed.

When distilled, truffles yield an acid liquid, a black oil, carbonate of ammonia, carbonic acid, and carburetted hydrogen. The charcoal contains magnesia, phosphate of lime, iron, and silica.*

Several experiments have been likewise made upon this plant, by Robert and Antoine, which confirm those of Bouillon La Grange.

19. *Reticularia portensis*, or *mucor septicus*. This singular vegetable substance appears upon the leaves of ivy and beech, but it is most common upon tan in hot houses. It has no certain size or figure, but has a fine yellow colour, and at first resembles cream beat up to froth. In 24 hours it acquires a thin filmy coat, becomes dry and full of a sooty powder adhering to downy threads. According to the analysis of Braconnot, its constituents are

Fungin, very much divided
A notable quantity of carbonate of lime
Albumen
An animal matter
A yellow fatty matter
Acetate of potash.†

20. *Tremella nostoc*. I place this singular vegetable substance here, on account of its resemblance to the preceding species. It has more similarity to an animal than a vegetable body. Some naturalists, indeed, are of opinion, that it is the spawn of the frog or of some similar animal. Braconnot subjected it to analysis, and extracted from 200 parts of it the following ingredients:—

Water	185·0
Cerasin	13·8
Mucus having a spermatic smell	1·2
Fat, Phosphate of lime, Carbonate of lime, Muriate of potash, Sulphate of potash, Potash — in small quantity.	
	200·0‡

* Bouillon La Grange, Ann. de Chim. xlvi. 197.
† Ann. de Chim. lxxx. 283. ‡ Ibid. lxxxvii. 265.

21. *Uredo Maydis.* This fungus, which frequently infects maize, was subjected to a chemical analysis by M. Dulong d'Astafort. He obtained

1 Fungin, constituting the basis of the fungus
2 An azotized matter, vegetable osmazome
3 A ditto, soluble in water, not in alcohol
4 Fatty matter
5 Wax
6 Brown colouring matter
7 An organic acid, partly free, partly combined with potash and magnesia
8 Phosphate of potash
9 Chloride of potassium
10 Sulphate of potash
11 Subphosphate of lime
12 An ammoniacal salt
13 Magnesia and lime
14 Iron.*

22. *Helvella mitra.* This mushroom, which varies very much in its characters, was subjected to an elaborate analysis by Schrader, in 1821.† From 1000 parts of it, dried in the open air, he obtained

Solid fatty matter . . .	10
Brown fixed oil	30
Mushroom sugar . . .	20
Phosphate of potash and fungate of ammonia	80
Albumen	12
Gummy mucus	54
Animo-vegetable extract . .	294
Fungin	396
Water	104
	1000

CHAPTER XVI.

OF ALGÆ.

Fuci are well known plants that vegetate in the sea, and by the combustion of which the impure alkaline body called kelp is obtained. Great quantities of fuci are burnt for this manufacture on the coasts of Scotland and Ireland. The same substance is made on the coast of Normandy, and is known in France by the name of *varec.* Some of these *fuci* were examined in 1777 by Macquer and Poulletier de la Salle, chiefly in order to determine the differ-

* Jour. de Pharmacie, xiv. 556. † Schweigger's Jour. xxxiii. 389.

ent saline substances which they contain, and the result of their experiments was published by Macquer, in the second edition of his dictionary.* But chemical analysis had at that time made too little progress to enable these gentlemen to determine with accuracy the nature of the different salts which they had to examine and separate. Besides, they did not distinguish between the different species of fuci; but subjected them indiscriminately to the destructive agency of fire.

After the discovery of iodine in kelp, the attention of chemists was naturally turned towards the fuci, by means of which kelp is procured. Several of them accordingly were examined in 1814, by Sir H. Davy, who detected traces of iodine in their ashes.† In 1815, an elaborate analysis of six different species of fucus was published by M. Gaultier de Claubry.‡ During the same year, Dr John, actuated by the same motive, a desire to determine whether iodine could be detected in fuci, made a set of experiments on the fucus vesiculosus, which he likewise published.§ Vauquelin had previously made some observations on the saccharine matter contained in different fuci, and had shown that it possessed the characters of manna, and this was fully confirmed by the subsequent experiments of M. Gaultier de Claubry. I shall in this Section give the constituents of the different species of fucus hitherto subjected to analysis.

1. *Laminaria saccharina.* This, which is very common on our coasts, consists of a single linear elliptic leaf, without any mid-rib. It has a tawny-green colour, and when full grown is about 5 feet long and 3 inches wide. But it varies prodigiously in size. Gaultier de Claubry analyzed this fucus by treating it first with water, then with alcohol. He examined it also by means of sulphuric acid, nitric acid, and potash. Finally, he subjected it to combustion and analyzed the ashes which remained behind. The constitution of it was found very complicated, as no fewer than 21 ingredients were extracted from it. The following were the substances:—

A saccharine matter. Manna
Mucilage in considerable quantity
Vegetable albumen
Green colouring matter
Oxalate of potash
Malate of potash
Sulphate of potash
Sulphate of soda
Sulphate of magnesia
Muriate of potash
Muriate of soda
Muriate of magnesia
Hyposulphite of soda‖
Carbonate of potash
Carbonate of soda
Hydriodate of potash
Silica
Subphosphate of lime
Subphosphate of magnesia
Oxide of iron probably united with phosphoric acid
Oxalate of lime.¶

* Under the article *Varec.*

† Phil. Trans. 1814, p. 505.

‡ Ann. de Chim. xciii. 75 and 113.

§ Schweigger's Jour. xiii. 464.

‖ I am not acquainted with this salt, nor do I know any method by which it could be formed. Probably the salt obtained by M. Gaultier de Claubry was sulphite of soda.

¶ Ann. de Chim. xciii. 83.

2. *Laminaria digitata.* This fucus is olive-coloured: it consists of a cylindrical stem, sometimes as thick as a walking stick, and about two feet long. The summit of the stalk suddenly dilates into a plain broad leaf, sometimes about a foot in breadth and a foot and a half in length, and divided almost to the base into sword-shaped, leafless segments, from four to about twelve in number. It is much employed in Scotland as a manure for the land. It was subjected to analysis by Gaultier de Claubry, who found in it the same constituents as in the preceding species, but in different proportions. The quantity of hydriodate of potash which it contained was much smaller.*

3. *Fucus vesiculosus.* This very common fucus consists of a dichotomous leaf, the edges of which are entire, and in the disc of which, near the edges, are immersed a number of air bladders about the size of a hazel nut, the use of which seems to be to cause the leaf to float in the water. From the analysis of Gaultier de Claubry, it appears to contain nearly the same constituents as the preceding species. He did not obtain the mucilaginous matter which the fucus saccharinus yields in such abundance. It contains less malic acid and less iodine than the fucus saccharinus, but its other constituents are the same.† John, from 100 parts of this fucus in a dry state, obtained the following constituents:—

A brownish-red slimy matter . . } Flesh-red extract, with some sulphate and muriate of soda . . . . }	4
A peculiar acid	—
Resinous fat	2
Sulphate of soda, with some common salt	3·13
Sulphate of lime, with much sulphate of magnesia and some phosphate of lime .	12·87
Trace of oxides of iron and manganese .	—
Membranous matter, or albumen of fuci .	78
Silica?	
	100·00‡

4. *Fucus serratus.* This fucus, like the preceding, is a dichotomous leaf; but its edges are serrated, and it wants the air bladders which characterize the vesiculosus. When analyzed by Gaultier de Claubry, it yielded abundance of mucilage and albumen. Alcohol separated from it a bitter substance of a brownish-red colour; likewise a green matter which precipitated when the alcohol was cooling, and which had a bitter and disagreeable taste. The salts are the same as in the preceding species; but it contains more iodine than fucus digitatus or vesiculosus; it contains likewise a greater quantity of carbonate of soda.§

5. *Halidrys siliquosa.* This fucus consists of a waved coriaceous stalk, about four feet long, greatly branched, dark-olive when fresh

* Ann. de Chim. xciii. 113. † Ibid. 116.
‡ Schweigger's Jour. xiii. 464. § Ann. de Chim. xciii. 119.

but quite black when dry. The fructifications have the appearance of little flat pods. When examined by Gaultier de Claubry, he obtained abundance of albumen, mucilage having a brownish-red colour, a very bitter substance soluble in alcohol, a substance of a greenish-brown colour, soluble in hot but insoluble in cold alcohol; the same salts as in the preceding species; but very little iodine. When dried it becomes covered with a notable quantity of manna sugar.*

6. *Chorda filum.* This consists of a cylindrical thread from the size of a fiddle string to that of a whip cord, and often twelve feet long. Its colour is olive-green. When dry it becomes nearly black; but by exposure to the air it acquires a yellowish or nearly white colour. When examined by Gaultier de Claubry, he found in it scarcely any sensible quantity of albumen, a good deal of mucilage, a very little green matter soluble in hot alcohol, and precipitating as the liquid cools: the same salts as in the preceding species; but very little iodine.†

The following table, drawn up by Mr Whitelaw, a manufacturer in Glasgow, from his own experiments, shows the proportion of iodine contained in some of the most common algæ on our sea coasts.

	Ratios of Iodine.
Laminaria digitata . . .	100
Laminaria bulbosa . . .	65
Laminaria saccharina . .	35
Fucus serratus	20
Fucus nodosus	15

The quantities of chloride of potassium in these algæ follow nearly the same ratio. Hence when kelp contains no potash we need hardly look for iodine in it.

CHAPTER XVII.

OF THE DISEASES OF PLANTS.

Having now given such an account of the parts of plants as the present imperfect state of vegetable chemistry permitted, it remains for us to point out the new substances generated in plants by disease, and to describe the properties of these substances. But though the diseases of plants are numerous and well marked, and though the effects which they produce on those vegetables which are employed as articles of food are often severely felt, yet little progress has been made, either in ascertaining the nature of these diseases, or the method of preventing or removing them. The following are

* Ann. de Chim. xciii. 121. † Ibid. p. 123.

the only observations, strictly chemical, which can be at present offered:—

1. Old trees are frequently affected with a kind of ulcer, the chief seat of which is under the bark. There the juices undergo a change, and acquire a certain acridity, which enables them to corrode and destroy the solid parts of the plant. We are indebted to Vauquelin for an examination of the sanies or morbid liquid which flows from the ulcer in these cases. He collected the matter which he examined from the elm, which is particularly subject to this disease.*

This liquor is sometimes nearly transparent like water, and having an acrid and saline taste; sometimes it is slightly coloured, sometimes blackish or brown. It deposits upon the sides of the ulcer a soft matter, which is insoluble in water. The bark over which the transparent sanies passes becomes white like chalk, acquires an alkaline taste, and effervesces powerfully with acids. It becomes friable, loses its fibrous texture, and exhibits the appearance of crystals. By means of a glass small rhomboids and four-sided prisms can be distinguished in it. When the liquid is dark-coloured, the bark assumes a black appearance, and looks as if covered with a coat of varnish. This black matter is sometimes in such quantity that it assumes the appearance of stalactites. It is soluble in water, has an alkaline taste, effervesces with acids.

The white matter which was deposited on the bark of the elm round the ulcer, was found composed of

Vegetable matter . . .	60·5
Carbonate of potash . .	34·2
Carbonate of lime . . .	5·0
Carbonate of magnesia . .	0·3
	100·0

The black shining matter consisted of carbonate of potash, and a peculiar substance which was obviously ulmin.

The destructive tendency of such ulcers in trees is sufficiently obvious. Vauquelin has shown, that to produce the quantity of white matter which surrounded the ulcer of the elm, and on which he made his experiments, 500 lbs. weight of the wood of the tree must have been destroyed.†

2. The blight is a disease which attacks the different species of corn, especially wheat, and in some seasons nearly destroys the crop. It begins first upon the leaves and stem, and at last, attacking the seed, destroys a considerable part, or even the whole of it, leaving a black matter in its place. Botanists have shown, that this black matter is a species of small fungus, which draws its nourishment from the wheat.‡ The wheat thus loaded with the black fungus was examined by Fourcroy and Vauquelin, in order to ascer-

* Ann. de Chim. xxi. 39. † Ibid.

‡ See an account of this fungus, with figures of it, and ingenious conjectures respecting its propagation, by Sir Joseph Banks. Nicholson's Jour. x. 225.

tain how far the experiments of former chemists were precise. The result of their examination was published in the sixth volume of the *Annales de Museum d'Histoire Naturelle.**

When the wheat was macerated with alcohol, it gave out a portion of acrid oil, of the consistence of butter, of a deep green colour. Water in which it was steeped acquired acidity, and when saturated with potash let fall an animal matter, mixed with phosphate of ammonia-and-magnesia, and held phosphate of potash in solution: of course the acid which it contained was the phosphoric. It still retained in solution a matter similar to gluten of wheat allowed to run into putrefaction. The residue, distilled, yielded water, holding in solution acetic acid and acetate of ammonia, a brown oil, and a quantity of charcoal amounting to nearly $\frac{1}{4}$th of the original weight. The result of the experiments was, that blighted wheat contained an acrid oil, putrid gluten, charcoal, phosphoric acid, phosphate of magnesia and ammonia, and phosphate of lime; but no traces of starch could be detected.

3. Barley is subject to a similar disease with wheat, and, doubtless, from the same cause. Einhof has subjected this grain, damaged by the rubigo, or blight, to a chemical examination. The result of his trials coincides pretty nearly with the experiments of Fourcroy and Vauquelin on blighted wheat. He could detect no starch in it. The infusion of it in water reddened vegetable blues, and contained an acid, which appeared to be the phosphoric. There was present a peculiar animal matter, differing in its properties from any of the principles of barley, and a quantity of charcoal.†

An account of the ergot of rye has been given in page 879 of this volume.

* No. xxxv. 332. † Gehlen's Jour. vi. 91.

DIVISION III.

OF VEGETATION.

We have now seen the different substances which are contained in plants, and of which they are composed; but we have still to examine the manner in which these substances are produced, and to endeavour to trace the different processes which constitute vegetation. But I must warn the reader not to expect complete information in this Chapter. The wonders of the vegetable kingdom are still but very imperfectly explored; many of the organs of plants are too minute for our senses; and scarcely a single process can be completely traced.

The multiplicity of operations continually going on in vegetables at the same time, and the variety of different, and even opposite substances, formed out of the same ingredients, and almost at the same place, astonish and confound us. The order, too, and the skill with which every thing is conducted, are no less surprising. No two operations clash; there is no discord, no irregularity, no disturbance; every object is gained, and every thing is ready for its intended purpose. This is too wonderful to escape our observation, and of too much importance not to claim our attention. Many philosophers, accordingly, distinguished equally by their industry and sagacity, have dedicated a great part of their lives to the study of *vegetation*. But hitherto their success has not been equal to their exertions. No person has been able to detect this *Agent*, always so busy, and performing such wonders, or to discover him at his work; nor have philosophers been much more fortunate in their attempts to ascertain the instruments which he employs in his operations. A great variety, however, of curious and interesting facts have been discovered. These I shall attempt in the following Chapters to collect and arrange, to point out their dependence on each other, and perhaps to deduce such consequences as obviously result from this mutual dependence.

CHAPTER I.

OF THE STRUCTURE OF PLANTS.

Little or no progress in the anatomy of plants was made by the ancients. The parts are so small, that it was impossible to discern them by the naked eye. And the application of microscopes, to

such investigations, had not been thought of. The first person who applied a microscope to the examination of the structure of plants, was Dr Hooke, in his *Micrographia*, published in 1667. He examined wood charcoal, and observed the opening of the spiral vessels and the small cells.

But the person to whom we are indebted for the first attempt to ascertain the structure of plants by dissection, and microscopical observations, was Dr Nehemiah Grew, a physician in London, and a member of the Royal Society. He began to turn his attention to the anatomy of plants as early as the year 1664. In 1670 he put an essay on the subject, which constitutes the first book of his *Anatomy of Plants*, into the hands of his brother-in-law, Dr Henry Sampson, who showed it to Mr Henry Oldenburg, at that time Secretary to the Royal Society. By Mr Oldenburg it was given to Dr Wilkins, Bishop of Chester, by whom the manuscript was read to the Royal Society. That learned body highly approved of it, and ordered it to be printed in 1671. At the suggestion of Dr Wilkins, Dr Grew was appointed curator to the Royal Society for the anatomy of plants. This occasioned the drawing up of the 2d, 3d, and 4th parts of his *Anatomy of Plants*, and of the various lectures on the same subject, which constitute a part of that work. The whole of these papers were printed between 1671 and 1677 inclusive, and read at intervals, during various meetings of the Royal Society. They were collected in 1682, and published in a folio volume, by the orders of the Society; constituting the book well known by the name of *Grew's Anatomy of Plants*—a very valuable and important work, and which, on account of the beauty and accuracy of the plates (83 in number), must always be referred to as a classical work on the subject.

In the year 1671, after the first part of Grew's work was printed, Malpighi, the celebrated Italian anatomist, a professor at Bologna, and a member of the Royal Society, sent over a manuscript treatise on the same subject. It was without figures, and much more concise than the essay of Dr Grew. The second part of Malpighi's treatise was received in 1674, after which the work was printed by the Royal Society. Thus Malpighi began and probably finished his investigations, without any previous knowledge of what had been already done by Grew. His work, as might have been expected from so great a master of anatomical knowledge, is excellent; though the plan is more circumscribed, and the quantity of information communicated upon the whole, is less than is to be found in the work of Grew.* There is a remarkable agreement in the sentiments of these two writers, respecting the subjects which they describe. This agreement is the more striking, because it holds, not merely in their descriptions, which might have been expected if both faithfully described only what they saw; but likewise in physiological opinions and deductions from their observations.

* In the *Anatome Plantarum* contained in the *opera omnia* of Malpighi, there are figures; but they are very rude, and convey but an imperfect representation of what the author describes.

Dr Stephen Hales, one of the most eminent names of that prolific era of British science, began his experiments on plants, soon after the death of Dr Grew, which took place in 1711. His discoveries were all laid before the Royal Society as soon as made. The first volume of his *Statical Essays*, which contain almost all his experiments on plants, was published in 1727. He made no microscopical observations on the anatomy of plants, but determined many curious facts respecting the motion of the sap. He modified several of the opinions of Grew and Ray, relative to the supposed circulation of the sap: and such was the weight of his reputation, that his sentiments seem to have been implicitly adopted by his contemporaries, though the recent discoveries of modern experimenters have shown us, that his opinions on the subject of the motion of the sap were not quite correct.

Duhamel de Monceau, a French philosopher of high and well-merited reputation, took up the subject when Hales laid it down. In his book, entitled *Physique des Arbres*, first published in 1757, he relates many ingenious experiments, confirming and extending the opinions of Hales. His experiments upon the annual productions of a layer of *wood* and of *liber*, are exceedingly varied and important, and leave no doubt respecting the accuracy of his views on the subject. He added but little to what had been previously ascertained, respecting the anatomy of plants, his chief attention having been turned to their physiology.

Perhaps the dissertation on the circulation of the sap of plants by M. de la Baisse, which gained the prize of the Bordeaux Academy, in 1733, ought to have been first mentioned. He concluded from his experiments and dissections, that there is an ascending and descending sap: that it ascends from the root to the summit of the plant through the wood, and that it descends through the bark. His views are exceedingly ingenious, and his experiments accurate, and, Duhamel alone excepted, he threw more light upon the motion of the sap, than any of his contemporaries, or even successors.

The same view of the subject nearly, was taken up by M. Cotta, in his dissertation which gained the prize in the year 1798, given by the Imperial Academy of Naturalists at Erlangen. He conceives that the leaves are the organs of digestion of the plant, and that the digested sap passes downward through the bark, to nourish all the different parts of the vegetable.

In the preceding imperfect historical sketch, many writers of considerable eminence on the anatomy of plants, have been omitted. For example, Van Marum, Mustel, Hedwig, Sprengel, Treviranus, Link, Rudolphi, Mirbel, &c., because they added but little to the anatomical facts previously ascertained. Bonnet's *Recherches sur l'usage des Feuilles*, and Sennebier's *Physiologie Vegetale*, in five octavo volumes, contain many interesting physiological views; but very imperfectly supported by anatomical observations. By far the most complete view which we have seen of the facts respecting the anatomy of plants hitherto ascertained, has been given by M. Kieser, in his

Memoire sur l'Organisation des Plantes, which gained the prize respecting the organization of plants, offered by the Teylerien Society, in the year 1812. The view of the physiology of plants contained in the same dissertation is also valuable, though not so full nor complete as that respecting the anatomy. Let us now take a view of the facts respecting the structure of plants, which have been established by the dissections of them that have been made—observing, in setting out, that the subject is encompassed by almost insuperable difficulties. The organs of vegetables are so small, that in order to make them visible to the eye, it is necessary to view them through a microscope magnifying several hundred times. This, of course, admits only a very small field, and the optical deceptions, to which we are liable in such cases, are very apt to mislead.

All plants seem to be composed of *cells* or *vesicles*, the walls of which are exceedingly thin and transparent. These cells are sometimes round, more frequently elongated, and not seldom hexagonal, on account of their mutually pressing against each other. In some cases the elongation is so great, as to give the cells the appearance of hexagonal columns pointed at their upper and lower extremity. The position of these columns is usually parallel to the axis of the stem; though some of them are horizontal.

When the cells press against each other, small intervals are left between them. These interstices form tubes called *intercellular canals*. They have no proper tunic, but only the walls of the cells. These intercellular canals are full of sap, and it is by them that the sap passes from the roots to the summits of the plant.

In some cases, these intercellular canals increase in size, so as to exceed the diameter of a cell at least ten times. Thus enlarged, they constitute what have been called the *proper vessels* of the plant. But these proper vessels do not differ, except in size, from the intercellular canals, and like them, have no other tunic than the walls of the cells.

The size of the cells varies from 0·006, to 0·0015 inch in diameter. A square inch of the leaf of the dianthus caryophyllus exhibits $3\frac{1}{3}$ millions of such cells. In annual succulent plants they are larger than in shrubs and trees. Each cell has its own wall, so that where two meet the partition is double.

In the cellular tissue, small round globules occur. Those in the cells are transparent. They are soluble in boiling water, and become starch. These small globules are supposed to be intended for the formation of new cells, in order to increase the size of the plant.

Very small green-coloured globules are also observed adhering to the walls of the cells. They constitute the green colouring matter of the plant, and are insoluble in water.

The cells have no communication with each other; yet they seem to be pervious to moisture, but in what way it enters is not understood. There are three kinds of cells, which are distinguished by their position.

1. Those of the bark and pith. They have the common ellipsoidal form.

2. The *elongated cells* of the *liber* and *wood*. They constitute the interior part of the bark of plants having a hard parenchyma, and of trees, and constitute the basis of the woody fibre. By age the cavities of these cells are obliterated. There are intercellular canals both in the liber and wood. It is among the elongated cells that the peculiar vessels of milky and resinous plants are formed.

3. The *cells* of the *medullary rays*. What are called medullary rays, consist of parenchyma passing horizontally from the pith to the bark, through the wood. They consist of horizontal elongated cells, the cavities of which are obliterated by age. They have intercellular canals.

The *pores* are oblique openings or slits in the epidermis, so small that in the epidermis of the kidney-bean, a square inch contains more than 300,000 pores. They are situated on the epidermis of the soft part of the plant, and are found chiefly on the under side of the leaves. They are surrounded by a very minute vessel, forming a net-work on the epidermis.

Spiral vessels exist also in the more perfect plants. They are composed of a fibre, twisted like a cork screw round an empty space. All the turns of the screw are contiguous and joined, so as to form a tube much larger than any of the intercellular canals. These vessels never occur in the bark or pith, but only in the *wood*. They occur in bundles, containing about thirty spiral vessels. A new bundle is formed every year on the outside of the old, constituting the annual layer of wood formed in every tree.

The spiral vessels are divided into *simple*, *annular*, *dotted*, *ramified*, *reticulated*, and in *rosaries*.

The *simple* consist of one or more fibres twisted round an empty space, so as to form a round tube. They have never any membrane between the turns of the fibre, and the fibres are not always close. They occur in all young plants, and are the only spiral vessels in bundles near the pith.

The *annular* are round tubes formed of rings soldered together. In herbaceous plants, they occupy the same place as the simple, viz., near the pith. The rings are often at some distance from each other, the interval being filled up by a membrane.

The *dotted* spiral vessels are formed by one or more fibres a little flattened, which, twisting like a cork-screw round an empty space, leave interstices between the spirals. These interstices are filled up by a membrane more or less thick and transparent, in which are small elliptic points, sometimes dark, sometimes transparent. Hence in them the spirals are always at a distance from each other. The simple or annular spiral tubes are converted into the dotted as the age of the plant advances. They always exist in the alburnum. They are much larger than the simple spiral tubes, and are sometimes visible to the naked eye. The spiral fibre is either simple or annular, and when two *dotted* vessels are contiguous, one membrane

at the place of contact serves both. The nature of the elliptical dots is unknown: they do not seem to be *pores* or *slits*.

When the spirals separate to a greater distance from each other, and, uniting from space to space, fill the interstices left among them more or less completely, by new branches of the original spiral vessels, they constitute what have been called *ramifying* and *reticulated* vessels. Such vessels have been observed only in a small number of plants.

The *vessels in rosaries*, as they have been called by M. Mirbel, who first observed them, occur only in the knots of the stem and in tuberculous roots. They are just the simple spiral vessels, with their diameters diminished from space to space, so as to give them the appearance of a string of beads.

The spiral vessels do not occur in the acotyledinous plants, except in the *equisetaceæ* and *ferns*, and in them only in small quantities. Till the spiral vessels appear, there is no pith, no elongated cells, no bark nor wood. In the monocotyledinous plants, the bundles of spiral vessels have no fixed place, but are dispersed through the whole extent of the stem. These plants have neither pith, nor liber, nor bark, nor medullary rays, nor wood. In the grasses, the centre of the stem is often hollow, and the bundles of spiral vessels are dispersed round that cavity, but not regularly.

In dicotyledinous plants, all the parts of the vegetable are developed. In the herbaceous division, the bundles of spiral vessels form one or more circles round the pith. These bundles are always surrounded by elongated cells. The spiral vessels never immediately touch the common cells, but are separated by elongated cells. From Kieser's observations it seems probable, that the number of spiral vessels thus surrounding the pith, correspond with that of the *stamina* of the flower.

The *wood* is formed of a circle of bundles of spiral tubes, surrounded by elongated cells. Every year a new circle is formed round the former, so that there are as many circles of wood as the tree has lived years.

Duhamel has shown, that a layer of *liber* is also formed every year, in contact with the new layer of wood. In spring, a mucilaginous liquid, called *cambium*, is interposed between the liber and wood. From this cambium the new layers of wood and of liber are formed. The wood at first is soft, and its spiral vessels transparent. It is then called *alburnum*. This alburnum, by the compression and final shutting up of the spiral vessels, &c., is gradually converted into perfect wood.

Various opinions have been formed respecting the uses of the spiral vessels. Some have supposed them *sap vessels*, others that they are analogous to the nerves of animals. But the weight of evidence seems to be on the side of those who, with Grew and Malpighi, consider them as air vessels.

The *epidermis* is the very thin membrane which envelopes the soft parts of plants, where there is parenchyma, as the leaves. It

is only wanting in the bark of trees, and in the more imperfect plants composed of tubes.

Pores are very small openings on the epidermis, round or oval, surrounded by an elevation and by an area filled with very fine vessels, communicating with the vessels of the epidermis. The diameter of the vessels of the epidermis does not exceed $\frac{1}{23000}$th of an inch. They form a net-work on the surface of the leaf, and terminate in the cells surrounding the spiral vessels. They probably communicate with the intercellular tubes.

Hairs consist of a row of cells arranged in a line. They are sometimes straight, sometimes pointed, and sometimes ramified.

CHAPTER II.

OF THE TEMPERATURE OF PLANTS.

It has long been a question among vegetable physiologists, whether plants, like animals, have the power of generating heat? This question has not hitherto been answered in a satisfactory manner. There can be no doubt that there is a particular temperature which suits best with every plant, and this temperature is connected with the climate to which the plant is suited. In this country, and indeed in all temperate climates, the difference between the temperature of the air at sunrise, when it is coldest, and about two hours after noon, when it is hottest, is very considerable. Now, wood being a bad conductor of heat, it is probable that, if a thermometer were plunged into the centre of a tree, we should find its temperature higher than that of the air at sun-rise, and lower than that of the air at two hours after noon.

Mr John Hunter bored a hole in a walnut-tree, 5 feet above the surface of the ground. The tree was 7 feet in circumference, the hole was 11 inches deep, and the bulb of a thermometer was plunged to the bottom of it.

On the 29th of March, 1786, the temperature of the atmosphere, at 6 in the morning, was 57°$\frac{1}{2}$, while that of the tree was 55°.

April 4th, at 5 in the evening, atmosphere 62°, tree 56°.

April 5th, at 6 in the evening, atmosphere 47°, tree 55°.

April 7, 3 afternoon, atmosphere 42°, tree 42°.

April 9, (a cold day, with snow, hail, and wind,) at 6 in the evening, atmosphere 39°, tree 45°.

In October, when the tree had ceased vegetating, he generally found its temperature warmer than the atmosphere. But in the winter of 1786, which was very cold, he found that the temperature of the tree gradually sunk as low as that of the air, which was

sometimes as low as 17°. Yet the sap, though its freezing point is as high as 32°, did not freeze; nor were the trees, for he tried eight or nine different species, killed. Whenever a tree was killed by the frost, the sap in it froze and split the tree with a loud crack. Whenever any part of a tree was frozen, that part was always killed.*

It appears also, that a young tree may be kept in ice for as long as twenty-one months without freezing, and without its powers of vegetation being destroyed. M. Demidoff, at Moscow, had a large botanic garden and green-house. M. Thouin, of Paris, was in the habit of sending him, almost every October, packages of young trees for this garden. The roots were covered with a mixture of earth and cow-dung, to the thickness of about $\frac{1}{6}$th of an inch. They were then tied in packets, containing each from eight to ten young trees, and covered all over with moss. They reached Moscow usually in three or four months. They were, after their arrival, placed in an ice-house till the cold of winter was over, and then the temperature was raised exceedingly slowly before they were planted. In the year 1787, one of these packages fell into the ditch of the ice-house, and remained enclosed in ice twenty-one months before it was discovered; yet the young trees, of which it consisted, vegetated very well when they were afterwards thawed and planted.†

A few observations upon the temperature of trees were made about the beginning of the present century, by M. Salomé.‡ He found, by observations continued for six months, that the temperature in the centre of the tree varied from 48°·2 to 66°·2; while that of the atmosphere, during the same time, varied from 35°·6 to 78°·8.

But the most extensive set of observations upon the temperature of trees, was made by M. Schübler at Tübingen, which were published in the year 1827.§ He found that the temperature in the centre of the tree at sun-rise, when the weather is clear, is always higher than that of the surrounding atmosphere. At mid-day, or rather during the hottest period of the day, the contrary is the case, the temperature of the air being higher than that of the centre of the tree.

This difference of temperature is the greater the larger the diameter of the tree is, and the nearer the surface of the earth in the tree the thermometer is placed. When the diameter of the tree is from 6 to 8 inches, the difference between the temperature of its centre and that of the air varies from 2°·25 to 4°·5. But when the diameter of the tree is two feet, the difference of temperature may amount to 11°·25, 14°·25, or even to 19°·25.

The difference between the temperature of the centre of the tree and the air, is always the greater the more rapidly the temperature of the air has changed. It is greatest, therefore, in clear weather,

* Phil. Trans. 1788, p. 7. † Ann. de Chim. et de Phys. xv. 84.
‡ Ann. de Chim. xl. 113.
§ Poggendorf's Annalen de Physick, x. 581.

when the temperature of the air at sun-rise is often lower than that at 2 P.M. by 22°·5, 27°, or even 33°·75.

As the tree is hotter than the air at sunrise, and colder at 2 P.M., it is obvious that there must be a point between these two extremes, at which the temperature of the centre of the tree and of the air must be equal.

Different trees exhibit little difference of temperature, provided the sizes be equal, and the position of the thermometer in each similar.

The cold to which the interior part of a tree may be reduced without injury, is very considerable. In the winter of 1826, Schübler observed, that the temperature of several trees which he examined, was as low as 0°·5; yet the sap did not freeze, nor was the vegetation of the trees injured. The trees upon which these observations were made, were elms and red pines.

These observations seem to leave little doubt that trees do not possess any means of generating heat, at least in any sensible quantity; but that their temperature depends upon that of the atmosphere in which they vegetate. But it seems equally evident, that the living plant possesses the power of preventing the freezing of its sap, though cooled down far below the degree at which this freezing would take place in the dead plant. Of the nature of this power we possess no conception; but it is obviously connected with the vitality of the plant.

There cannot be a doubt, however, that in certain circumstances, plants are capable of generating very considerable quantities of heat. Hubert observed, that the stamina of the *arum cordifolium*, at the moment they shed their pollen, produce so much heat, that twelve of them, placed round the bulb of a thermometer, raised it from 79° to 143°. The observation was repeated several times with the same result.* Senebier observed, that the stamina of the *arum maculatum*, under the same circumstances, were 15°·75 hotter than the surrounding atmosphere. Dr Schultz of Berlin, on the 1st of May, 1833, when the thermometer stood at 61°·25, applied a thermometer to the flowers of the *caladium pinnatifidum*, which was emitting a disagreeable ammoniacal smell. It gradually rose to 81°.†

Saussure examined the flowers of a great many plants, at the time of the bursting of the pollen, and only found a sensible quantity of heat evolved in three of them. 1. The stamina of the *cucurbita melo-pepo* were from 1°·8 to 3°·6 hotter than the air. 2. Those of the *bignonia radicans* were from 0°·9 to 3°; those of the *polyanthes tuberosa* about 0°·6 hotter than the air.‡

These evolutions of heat have been shown by Saussure to be the consequence of the great quantity of oxygen absorbed by the sexual organs of the plants at the instant of fecundation. The stamina of

* Jour. de Phys. lix. 281. † Jour. de Pharmacie, xx. 116.
‡ Ann. de Chim. et de Phys. xxi. 279.

the *arum maculatum*, for example, absorb 200 times their bulk of oxygen gas, and convert it into carbonic acid. The following table exhibits the volumes of oxygen gas absorbed by 1 volume of the flowers and leaves of various plants, as determined by Saussure:—*

	Oxygen absorbed.	
	By the flowers.	By the leaves.
Cheiranthus incanus—6 P.M.	11	4
Ditto, double	7·7	
Polyanthes tuberosa—9 A.M.	9	3
Ditto, double	7·4	
Tropæolum majus—9 A.M.	8·5	8·3
Ditto, double	7·25	
Datura arborea—10 A.M.	9	5
Passiflora serratifolia—8 A.M.	18·5	5·25
Daucus carota—6 P.M.	8·8	7·3
Hebiscus speciosus—7 A.M.	8·7	5·1
Hypericum calicinum—8 A.M.	7·5	7·5
Cucurbita melo-pepo, male flowers—7 A.M.	12	6·7
Ditto, female flowers—7 A.M.	3·5	
Lilium candidum—11 A.M.	5	2·5
Typha latifolia—9 A.M.	9·8	4·25
Fagus castanea—4 P.M.	9·1	8·1

From these facts it is evident, that plants sometimes generate heat as well as animals; and, from Saussure's observations, it follows, that the process in plants is similar to that in animals, namely, absorbing oxygen gas and converting it into carbonic acid. Doubtless the organs by which these changes are effected in plants, are similar to those that perform the same process in animals, though the texture in the former is so exceedingly minute, that it is impossible to ascertain that similarity by observation.

There can be no doubt that a certain temperature is necessary for every plant, to enable it to produce flowers and fruits. As this temperature depends in a great measure upon the climate, the consequence is, that certain plants, according to the temperature at which they blossom, are suited to particular climates, in which alone they vegetate in perfection. The following table, drawn up by M. Schübler from a set of observations made by him at Tübingen on the Necker, in north latitude 48° 26′, exhibits the temperature of the plants and of the air, at the time of flowering, of a considerable number of plants:—†

* Ann. de Chim. et de Phys. xxi. 283. † Poggendorf's Annalen, x. 592.

PLANTS.	Day of 1825.	TEMPERATURE AT SUN-RISE. Of the air.	Of the plant.	TEMPERATURE AT TWO P. M. Of the air.	Of the plant.	Mean temp. of the 5 preceding days.	Mean temp. from 25th March to the date in table.
Daphne Mezerium, Viola oderata, Leucojum vernum. } blossom.	March 28.	27°·5	31°·775	56°·75	53°·375	43°·025	38°·37
Ribes grossularia } in leaf. —— et rubrum } Scilla bifolia, blossoms.	April 3.	28°·625	31°·875	50°·45	47°·75	48°·575	40°·3
Sambucus nigra, —— racemosa, } in leaf. Lonicera tartarica, ribes nigrum Ulmus campestris, } blossom. populus tremula,	April 10.	29°·75	34°·475	64°·625	60°·125	44°·825	41°·675
Pinus larix, prunus padus, Lonicera Xylosteum, } in leaf. corylus avellana. Pulmonaria officinalis, } blossom. Anemone nemorosa,	April 16.	35°·375	31°·55	62°·375	59°	53°·375	44°·1
Euonymus Europæus, viburnum opulus, berberis vulgaris, } in leaf. Æsculus hippocastanum, salix fragilis,	April 17.	51°·125	52°·25	53°·825	52°·7	53°·6	44°·28
Pinus larix, } blossom. salix fragilis,	April 18.	27°·5	32°	41°·45	38°·075	53°·6	44°·55
Carpinus betulus in leaf. Buxus sempervirens, } blossom. ribes alpinum,	April 21.	36°·5	34°·7	59°	56°·975	42°·35	43°·79
Pyrus communis, } in leaf. prunus domestica, } Alnus glutinosa, blossoms.	April 24.	52°·7	54°·5	71°·375	70°·25	45°·05	44°·31
Acer pseudo platinus, } in leaf. vitis vinifera, Ribes rubrum, } blossom. cardamine pratensis,	April 25.	47°	47°·75	67°·325	65°·75	43°·55	44°·78
Fagus sylvatica, } in leaf. acer campestre	April 26.	51°·125	52°·25	72°·95	69°·125	53°·6	45°·12
Tilia europæa, } in leaf. sorbus aucuparia, } Acer platanoides, } blossom. prunus padus,	April 29.	43°·7	45°·5	71°·375	—	60°·35	46°·35
Ulmus campestris, } in leaf. rhamnus catharticus, } Prunus cerasus et avium, blossom.	April 30.	51°·575	53°·6	68°·45	63°·05	59°·675	46°·625
Rhamnus fragila, } in leaf. populus alba et italica, }	May 1.	44°·375	—	66°·875	65°·3	60°·125	46°·94
Pyrus communis, } blossom. betula alba, } Sambucus racemosa, }	May 2.	44°·825	47°·525	70°·25	68°·125	60°·575	47°·14
Quercus robur, } in leaf. rhus typhinum, } Juglans regia. }	May 4.	36°·5	38°·975	72°·5	69°·575	56°·975	47°·5
Robinia pseudacacea, in leaf.	May 5.	43°·25	45°·95	78°·125	74°·075	56°·75	47°·66
Robinia inermis et hispida, do. Acer campestre, } blossom. virburnum lantana, }	May 6.	46°·4	50°	83°·75	79°·7	56°·75	47°·93
Fraxinus excelsior, in leaf. Juniperus communis, blossom.	May 8.	57°·2	—	68°·45	—	60°·025	48°·67

PLANTS.	Day of 1825.	TEMPERATURE AT SUN-RISE. Of the air.	Of the plant.	TEMPERATURE AT TWO P. M. Of the air.	Of the plant.	Mean temp. of the 5 preceding days.	Mean temp. from 25th March to the date in table.
Pyrus malus, acer pseudo platinus, Morus alba, } blossom.	May 9.	45°·95	50°	68°·45	64°·625	61°·925	48°·99
Syringa vulgaris, lonicera xylosteum, } blossom.	May 11.	44°·825	47°·75	68°	—	65° 525	49°·1
Cratœgus oxyacantha, berberis vulgaris, platinus orientalis, } blossom.	May 13.	44°·375	—	63°.5	60°·8	57°·875	49°·57
Æsculus hippocastanum, lonicera tartarica, pyrus cydonia, } blossom	May 16.	34°·7	32°·225	54°·5	52°·25	51°·125	49°·5
Viburnum opulus, secale cereale, } blossom.	May 27.	48°·875	52°·25	65°·75	63°·5	61°·025	50°
Lonicera caprifolium, hordeum vulgare hybernum, } blossom.	June 1.	48°·875	49°·55	54°·5	53°·375	51°·125	50°·225
Vitis vinifera, rubus fruticosa, sambucus nigra, } blossom.	June 15.	54°·5	57°·825	74°·75	71°·825	65°·975	51°·01
Rosa canina, triticum spelta hybernum, } blossom.	June 20.	40°·325	43°·7	74°·75	71°·825	58°·55	51°·87
Tamarix Germanica, hordeum distichum æstivum, } blossom.	July 1.	52°·7	—	75°	71°·825	59°·9	52°·54
Tilia Europæa, acorus calamus, avena sativa, } blossom.	July 10.	54°·5	57°·825	70°·25	67°·325	59°·225	53°·13
Linum usitatissimum, spiræa ulmaria, solanum tuberosum, melilotus officinalis } blossom. Hottest day.	July 20.	53°·825	56°·75	87°·125	83°·75	68°·45	54°·16
Harvest of tritium spelta begins. Atropa belladonna, blossoms.	July 26.	54°·5	—	68°	—	60°·575	54°·54
Panicum milium, vicia faba, portulaca oleracea, } blossom.	Aug. 1.	61°·25	64°·625	77°	74°·075	60°·125	54°·81
Tanacetum vulgare, coriandrum sativum, phaseolus vulgaris, } blossom.	Aug. 12.	46°·625	—	62°·375	61°·25	61°·475	55°·56
Aconitum napellus, nicotiana rustica, } blossom.	Aug. 16.	55°·625	56°·75	61°·25	60°·575	58°·1	55°·65
Datura stramonium, centauria benedicta, cicer arietinum, artemisia dracunculus, } blossom	Sep. 1.	42°·125	44°·825	69°·125	65°·75	67°·325	56°·4
Aster Chinensis, dahlia pinnata, polygonum orientale, } blossom.	Sep. 16.	57°·2	59°	69°·125	66°·2	61°·7	56°·5
Vitis vinifera, ripe. Tagetes patula, blossom.	Sep. 21.	51°·575	—	77°	73°·625	61°·925	56°·64
General vintage. Helianthus tuberosus, blossoms	Oct. 18.	45°·95	47°.75	50°	49°·55	50°·45	57°·47
Trees begin to lose their leaves. Hedera helix, blossoms.	Nov. 9	29°·75	33°·125	51°·125	48°·875	43°·925	56°·32
Severest cold of the winter, 1825-6.	Jan. 30, 1826.	−1°·3	0°·5	16°	16°·7	16°·25	—

It appears from the experiments of Edwards and Colin, that wheat, oats, and barley, are incapable of vegetating in a temperature of 113°, and that they do not thrive in any country whose mean temperature exceeds 65°.*

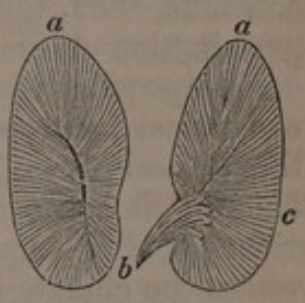
CHAPTER III.

OF GERMINATION.

1. NATURAL historians have proved, by a very complete induction of facts, that all plants arise from seeds. The pretended exceptions have disappeared, one after another, as our knowledge of vegetables increased: and now there remains scarcely a single objection entitled to the smallest regard. The attempt of Girtanner† to revive the doctrine of equivocal generation, deserves no attention whatever; because his conclusions are absolutely incompatible with the experiments of Mr Sennebier upon the very substance on which his theory is founded.

A seed consists of three parts; namely, the *cotyledons*, the *radicle*, and the *plumula*, which are usually enclosed in a cover.

If we take a garden bean, we may perceive each of these three parts with great ease; for this seed is of so large a size, that all its organs are exceedingly distinct. When we strip off the external coats of the bean, which are two, and of different degrees of thickness in different parts, we find that it easily divides into two lobes, pretty nearly of the same size and figure. Each of these lobes is called a *cotyledon* (*fig. a.*) The cotyledons of the bean, then, are two in number.



Near that part of the lobes which is contiguous to what is called the *eye* of the bean, there is a small round white body (*b*), which comes out between the two lobes. This body is called the *radicle.*

Attached to the radicle there is another small round body (*c*), which lies between the cotyledons, and wholly within them, so that it cannot be seen till they are separated from each other. This body is called the *plumula.*

The appearance and shape of these three parts vary much in different seeds, but there is no seed which wants them. The figure and size of the seed depend chiefly upon the cotyledons. This is evidently the case with the bean, and it is so with all other seeds. The number of cotyledons is different in different seeds. Some seeds have only one cotyledon, as the seeds of wheat, oats, barley,

* Jour. de Pharmacie, xxii. 210. † Ann. de Chim. xxxiv. 35.

and the whole tribe of grasses; but most seeds, like the bean, have two cotyledons.

2. When a seed is placed in a situation favourable to vegetation, it very soon changes its appearance. The radicle is converted into a root, and sinks into the earth, the plumula on the other hand, rises above the earth, and becomes the trunk or stem. When these changes take place, the seed is said to *germinate*: the process itself has been called *germination*. Seeds do not germinate equally and indifferently in all places and seasons. Germination, therefore, is a process which does not depend upon the seed alone; something external must also affect it.

3. It is a well known fact, that seeds will not germinate unless *moisture* have access to them; for seeds, if they are kept perfectly dry, never vegetate at all, and yet their power of vegetation is not destroyed. *Water*, then, is essential to germination. Too much water, however, is no less prejudicial to most seeds than none at all. The seeds of water plants, indeed germinate and vegetate extremely well in water; but most other seeds, if they are kept in water beyond a certain time, are rotted and destroyed altogether.

4. It is well known also, that seeds will not germinate, even though supplied with water, provided the temperature be below a certain degree. No seed, for instance, on which the experiment has been tried, can be made to vegetate at or below the freezing point: yet this degree of cold does not injure the vegetating power of seeds; for many seeds will vegetate as well as ever after having been frozen, or after having been kept in frozen water. We may conclude, then, that a certain degree of heat is necessary for the germination of seeds: and every species of plant seems to have a degree peculiar to itself, at which its seeds begin to germinate; for every seed has a peculiar season at which it begins to germinate, and this season varies with the temperature of the air. Mr Adanson found that seeds, when sown at the same time in France and in Senegal, always appeared sooner above ground in the latter country, where the climate is hotter than in France.*

5. Seeds, although supplied with moisture and placed in a proper temperature, will not germinate, provided atmospherical air be completely excluded from them. Mr Ray found that grains of lettuce did not germinate in the vacuum of an air-pump, but they began to grow as soon as air was admitted to them.† Homberg made a number of experiments on the same subject, which were published in the *Memoirs of the French Academy* for the year 1693. He found, that the greater number of seeds which he tried refused to vegetate in the vacuum of an air-pump. Some, however, did germinate: but Boyle, Muschenbroek, and Boerhaave, who made experiments on the same subject in succession, proved beyond a doubt that no plant vegetates in the vacuum of an air pump; and that in those cases in which Homberg's seeds germinated, the vacuum was

* Encyc. Method. Physiol. Veget. 124. † Phil. Trans. No. liii.

far from perfect, a quantity of air still remaining in the receiver. It follows, therefore, that no seed will germinate unless atmospherical air, or some air having the same properties, have access to it. It is for this reason that seeds will not germinate at a certain depth below the surface of the earth.

Mr Scheele found that beans would not germinate except oxygen gas were present: Mr Achard afterwards proved, that oxygen gas is absolutely necessary for the germination of all seeds, and that no seed will germinate in azotic gas, or hydrogen gas, or carbonic acid gas, unless these gases contain a mixture of oxygen gas. These experiments have been confirmed by Mr Gough, Mr Cruikshank, and many other philosophers.* It follows, therefore, that it is not the whole atmospheric air, but merely the oxygen gas which it contains, that is necessary for the germination of seeds.

Nay, Mr Humboldt has ascertained that seeds vegetate more rapidly when steeped in chlorine, or when watered with it; and this substance is well known for the facility with which it decomposes water and sets at liberty oxygen. It seems even to augment the vegetative power of seeds. At Vienna several seeds which had been long kept, and which had constantly refused to germinate, grew readily when treated with it.†

6. Light also has considerable influence on the germination of seed. Ingenhousz found that seeds always germinate faster in the dark than when exposed to the light.‡ His experiments were repeated by Mr Sennebier with equal success.§ But the Abbé Bertholin, who distinguished himself so much by his labours, to demonstrate the effect of electricity on vegetation, objected to the conclusions of these philosophers, and affirmed that the difference in the germination of seeds in the shade and in the light was owing, not to the light itself, but to the difference in the moisture in the two situations; the moisture evaporating much faster from the seeds in the light than from those in the shade; and he affirmed, that when precautions were taken to keep the seeds equally moist, those in the sun germinated sooner than those in the shade.‖ But when Mr Sennebier repeated his former experiments, and employed every possible precaution to ensure equality of moisture in both situations, he constantly found the seeds in the shade germinate sooner than those in the light.¶ We may conclude, therefore, that light is injurious to germination; and hence one reason for covering seeds with the soil in which they are to grow. But from the recent experiments of Saussure, there is reason to believe that light is only

* Carradori, indeed, has attempted to show that seeds will begin to germinate without oxygen. (Ann. de Chim. xlviii. 188.) But we learn from the experiments of Saussure, that the water in which the seeds in these cases are steeped, contains in solution as much oxygen as is sufficient to enable the seeds just to commence germination, but not to make any progress. (Recherches Chimiques sur la Vegetation, p. 3.)

† Jour. de Phys. xlvii. 63. ‡ Experiences sur les Vegetaux, ii.

§ Mem. Physico-Chimiques, iii. 41. ‖ Jour. de Phys. 1789, December.

¶ Encyc. Method. Physiol. Veget. 126.

injurious in consequence of the heat which it produces; for when the direct rays of the sun were intercepted, though light was admitted, the germination of the seeds was not sensibly retarded.*

7. Thus we have seen that seeds will not germinate unless *moisture*, *heat*, and *oxygen* be present. Now, in what manner do these substances affect the seed? What are the changes which they produce?

It was observed before, that all seeds have one or more cotyledons. These cotyledons contain a quantity of farinaceous matter, laid up on purpose to supply the embryo plant with food as soon as it begins to require it.† This food, however, must undergo some previous preparation before it can be applied by the plant to the formation or completion of its organs. It is probable that all the phenomena of germination, which we can perceive, consist in the chemical changes which are produced in that food, and the consequent development of the organs of the plant.

When a seed is placed in favourable circumstances, it gradually imbibes moisture, and very soon after emits a quantity of carbonic acid gas, even though no oxygen gas be present.‡ If no oxygen gas be present, the process stops here, and no germination takes place; but if oxygen gas be present, a portion of it is converted into carbonic acid gas. From the experiments of Saussure, it appears, that if seeds be left to germinate in a determinate portion of oxygen gas or common air, the bulk of that gas is not altered; the carbonic acid formed being equal to the oxygen which has disappeared. Hence it follows, that the carbonic acid contains in it exactly the whole oxygen consumed.§ No oxygen, then, is absorbed by the seed; or at least, if it be absorbed, none of it is retained, the whole being thrown out in combination with carbon. The quantity of oxygen thus changed into carbonic acid by the germination of seeds, is in some measure proportional to the weight of the seed: but some seeds require more than others. In the experiments of Saussure, wheat and barley, weight for weight, consumed less oxygen than peas; while peas consumed less than beans and kidney-beans. The oxygen consumed by wheat and barley amounts to between $\frac{1}{1000}$th and $\frac{1}{2000}$th of their weight; while that consumed by beans and kidney-beans may amount to $\frac{1}{100}$th part of their weight.‖ Similar experiments were made by Dr Woodhouse.¶

From the observation of M. T. de Saussure, it appears that during the first stage of germination, the carbonic acid evolved exceeds the bulk of the oxygen absorbed, but afterwards the oxygen absorbed exceeds the bulk of the carbonic acid evolved. Azotic gas he found was always absorbed during germination in air, but

* Recherches Chimiques sur la Vegetation, p. 23.

† In some seeds, as wheat, the food is laid up not in the cotyledon but in the *albumen* of the seed.

‡ Gough, Manch. Mem. iv. 315. Cruickshank, Rollo on Diabetes, p. 452.

§ Jour. de Phys. xlix. 92. ‖ Recherches, p. 13.

¶ He tried the seeds of the zea mays, apium petroselinum, lactuca sativa, cucurbita citrulla, phaseolus sativus, sisymbrium sativum, raphanus sativa. They changed oxygen into carbonic acid. Nicholson's Jour. ii. 161.

not during germination in oxygen gas, or a mixture of equal volumes of oxygen and azotic gases.*

It does not appear that any water is decomposed during the process of germination, at least we have no evidence that it is so. Neither hydrogen nor oxygen gas are emitted. It would not be surprising if a portion of water, so far from being decomposed, were actually formed by the union of its constituents previously existing in the grain. When Saussure dried seeds at a certain temperature before germination, and afterwards brought them to the same degree of dryness after germination, he always found that the loss of weight was greater than it ought to have been. Thus 73 peas, which together (when dried at 77°) weighed 200 grains, when left with five times their weight of water in a vessel full of air, and standing over mercury for two days, germinated, and produced 4½ cubic inches of carbonic acid. They were taken out and dried slowly at the same temperature; during their drying they changed 4½ cubic inches more of oxygen into carbonic acid. Now these 9 inches of carbonic acid contain 1·7 grains of carbon. The water in which peas had been placed while germinating, when evaporated to dryness, left 0·75 grains of mucilaginous matter. Thus the peas, by germinating and drying, ought to have lost only 2·45 grains, leaving a residue of 197·55 grains. But their weight was only 189 grains. So that they had lost 8 grains more than can be accounted for by the mucilage taken up by the water and carbonic acid formed. We are obliged to suppose this loss owing to water. From Saussure's experiments, this water seems to be formed or set at liberty during the drying of the seeds, for the quantity of it always increased with the slowness of the process of drying.†

Several seeds, by germinating, acquire a sweetish taste. Hence it has been supposed, that the mucilage which they contain is converted into saccharine matter. We see that the carbon is diminished by germination; and unless water be formed, the proportion of hydrogen and oxygen must be proportionably augmented. It is obvious from the process of malting, that heat is generated during germination. I have seen the radicles of barley, when kept without turning on the malt-floor, shoot out half an inch in a single night, and the heat rise as high as 100°.

So far seems to be the work of chemistry alone; at least we have no right to conclude that any other agent interferes; since hay, when it happens to imbibe moisture, exhibits nearly the same processes. Carbonic acid gas is evolved, oxygen gas is absorbed, heat is produced so abundantly, that the hay often takes fire: at the same time a quantity of sugar is formed. It is owing to a partial change of the same kind that old hay generally tastes much sweeter than new hay. Now we have no reason to suppose that any agents peculiar to the vegetable kingdom reside in hay; as all vegetation, and all power of vegetating, are evidently destroyed.

* Memoires de la Societé Physique et d'Hist. Nat. de Geneve, vi. 545.

† Saussure, Recherches Chimiques sur la Vegetation, p. 17.



But when the farina in the seeds of vegetables is converted into sugar, a number of vessels make their appearance in the cotyledon. The reader will have a pretty distinct notion of their distribution by inspecting the figure. These vessels may indeed be detected in many seeds before germination commences, but they become much more distinct after it has made some progress. Branches from them have been demonstrated by Grew, Malpighi, and Hedwig, passing into the radicle, and distributed through every part of it. These evidently carry the nourishment prepared in the cotyledons to the radicle; for if the cotyledons be cut off, even after the processes above described are completed, germination, as Bonnet and Sennebier ascertained by experiment, immediately stops. The food therefore is conveyed from the cotyledons into the radicle; the radicle increases in size, assumes the form of a *root*, sinks down into the earth, and soon becomes capable of extracting the nourishment necessary for the future growth of the plant. Even at this period, after the radicle has become a perfect root, the plant, as Sennebier ascertained by experiment ceases to vegetate if the *cotyledons* be cut off. They are still, then, absolutely necessary for the vegetation of the plant.

The cotyledons now assume the appearance of leaves, and appear above the ground, forming what are called the *seminal leaves* of the plant. After this the *plumula* gradually increases in size, rises out of the earth, and expands itself into branches and leaves. The seminal leaves, soon after this, decay and drop off, and the plant carries on all the processes of vegetation without their assistance.

As it does not appear that there is any communication between the cotyledons and the plumula, it must follow that the nourishment passes into the plumula from the radicle; and accordingly we see that the plumula does not begin to vegetate till the radicle has made some progress. Since the plant ceases to vegetate, even after the radicle has been converted into a root, if the cotyledons be removed before the plumula is developed, it follows that the radicle is insufficient of itself to carry on the processes of vegetation, and that the cotyledons still continue to perform a part. Now we have seen already what that part is; they prepare *food* for the nourishment of the plant. The root, then, is of itself insufficient for this purpose. When the cotyledons assume the form of seminal leaves, it is evident that the nourishment which was originally laid up in them for the support of the embryo plant is exhausted, yet they still continue as necessary as ever. They must therefore receive the nourishment which is imbibed by the root; they must produce some changes on it, render it suitable for the purposes of vegetation, and then send it back again to be transmitted to the plumula.

After the plumula has acquired a certain size, which must be at least a *line*, if the cotyledons be cut off, the plant as Mr Bonnet

ascertained by a number of experiments, afterwards repeated with equal success by Mr Sennebier, does not cease to vegetate, but it continues always a mere pigmy: its size, when compared with that of a plant whose cotyledons are allowed to remain, being only as 2 to 7.*

When the plumula has expanded completely into leaves, the cotyledons may be removed without injuring the plant, and they very soon decay of themselves. It appears, then, that this new office of the cotyledons is afterwards performed by that part of the plant which is above ground.

Thus we have traced the phenomena of germination as far as they have been detected. The facts are obvious; but the *manner* in which they are produced is a profound secret. We can neither explain how the food enters into the vessels, how it is conveyed to the different parts of the plant, how it is deposited in every organ, nor how it is employed to increase the size of the old parts, or to form new parts. These phenomena are analogous to nothing in mechanics or chemistry, but resemble exactly the organization and nourishment of animals. They belong therefore to that difficult branch of science known by the name of Physiology.

M. Vogel of Munich has made some experiments on the germination of seeds which deserve to be mentioned. He found, 1. That seeds will not germinate in carbonate of barytes, hydrate of barytes, iodine bruised and moistened, kermes mineral, golden sulphur of antimony, oxide of bismuth, arseniate of lead, green oxide of chromium. 2. That they germinate, though very feebly, in carbonate of magnesia, copper filings, sulphuret of antimony, red oxide of mercury, aqueous solution of iodine. 3. That they germinate perfectly well in carbonate of lime, carbonate of strontian, litharge, red oxide of lead, phosphate of lead, black oxide of manganese, calomel, cinnabar.†

CHAPTER IV.

OF THE FOOD OF PLANTS.

Plants, after they have germinated, do not remain stationary, but are continually increasing in size. A tree, for instance, every season adds considerably to its former bulk. The root sends forth new shoots, and the old ones become larger and thicker. The same increment takes place in the branches and the trunk. When we examine this increase more minutely, we find that a new layer of wood, or rather of alburnum,‡ has been added to the tree in every

* Encyc. Method. Physiol. Veget. 42. † Jour. de Pharmacie, xvi. 406.

‡ The *wood*, when we inspect it with attention, is not, through its whole extent, the same; the part of it next the bark is much softer and whiter, and more juicy than the rest, and has for that reason obtained a particular name; it has been called the *alburnum* or *aubier*. The *perfect wood* is browner, and harder, and denser than the alburnum, and the layers increase in density the nearer they are to the centre.

part, and this addition has been made just under the bark. We find, too, that a layer of alburnum has assumed the appearance of perfect wood. Duhamel has shown also that a new layer of liber next to the alburnum, is formed every year. Besides this addition of vegetable fibre, a great number of leaves have been produced, and the tree puts forth flowers, and forms seeds.

It is evident from all this, that a great deal of new matter is continually making its appearance in plants. Hence, since it would be absurd to suppose that they *create* new matter, it must follow that they receive it by some channel or other. Plants, then, require food as well as animals. Now, what is this food, and whence do they derive it? These questions can only be answered by an attentive survey of the substances which are contained in vegetables, and an examination of those substances which are necessary for their vegetation. If we could succeed completely, it would throw a great deal of light upon the nature of soils and of manures, and on some of the most important questions in agriculture. But we are far indeed at present from being able to examine the subject to the bottom.

1. In the first place, it is certain that plants will not vegetate without water; for whenever they are deprived of it they wither and die. Hence the well-known use of rains and dews, and the artificial watering of ground. Water, then, is at least an essential part of the food of plants. But many plants grow in pure water; and therefore it may be questioned whether water is not the only food of plants. This opinion was adopted very long ago, and numerous experiments have been made in order to demonstrate it. Indeed it was the general belief of the 17th century; and some of the most successful improvers of the physiology of plants, in the 18th century, have embraced it. The most zealous advocates for it were, Van Helmont, Boyle, Bonnet, Duhamel, and Tillet.

Van Helmont planted a willow which weighed 5 pounds, in an earthen vessel filled with 200 lbs. of soil previously dried in an oven, and then moistened with rain water. This vessel he sank into the earth, and he watered his willow, sometimes with rain, and sometimes with distilled water. After five years it weighed 169¼ lbs., and the earth in which it was planted, when again dried, was found to have lost only 2 ounces of its original weight.* Here, it has been said, was an increase of 164 lbs., and yet the only food of the willow was pure water; therefore it follows that pure water is sufficient to afford nourishment to plants. The insufficiency of this experiment to decide the question was first pointed out by Bergmann in 1773.† He showed, from the experiments of Margraff, that the rain water employed by Van Helmont contained in it as much earth as could exist in the willow at the end of five years. For, according to the experiments of Margraff, 1 pound of rain water contains 1 grain of earth.‡ The growth of the willow, therefore, by no means

* Opera Van Helmont, p. 105. Complexionum atque Mistionum Elementalium Figmentum, Sect. 30.

† Opusc. v. 92.

‡ Ibid. ii. 15 and 19.

proves that the earth which plants contain has been formed out of water. Besides, as Mr Kirwan has remarked,* the earthen vessel must have often absorbed moisture from the surrounding earth, impregnated with whatever substance the earth contained; for unglazed earthen vessels, as Hales† and Tillet‡ have shown, readily transmit moisture. Hence it is evident that no conclusion whatever can be drawn from this experiment; for all the substances which the willow contained, except water, may have been derived from the rain water, the earth in the pot, and the moisture imbibed from the surrounding soil.

The experiments of Duhamel and Tillet are equally inconclusive; so that it is impossible from them to decide the question, whether water be the sole nourishment of plants or not? But all the attempts hitherto made to raise plants from pure water have failed; the plants vegetating only for a certain time, and never perfecting their seeds. These experiments were made by Hassenfratz, Saussure, and others, with the same unfavourable result. Duhamel found, that an oak, which he had raised by water from an acorn, made less and less progress every year. We see, too, that those bulbous roots, such as hyacinths, tulips, &c., which are made to grow in water, unless they be planted in the earth every other year, refuse at last to flower, and even to vegetate; especially if they produce new bulbous roots annually, and the old ones decay. From all these facts and experiments, it is reasonable to conclude that water is not the sole food of plants.§

So far, indeed, is water from being the sole food of plants, that in general only a certain proportion of it is serviceable, too much being equally prejudicial to them as too little. Some plants, it is true, grow constantly in water, and will not vegetate in any other situation; but the rest are entirely destroyed when kept immersed in that fluid beyond a certain time. Most plants require a certain degree of moisture in order to vegetate well. This is one reason why different soils are required for different plants. Rice, for instance, requires a very wet soil: were we to sow it in the ground on which wheat grows luxuriously, it would not succeed: and wheat, on the contrary, would rot in the rice ground.

We should, therefore, in choosing a soil proper for the plants which we mean to raise, consider the quantity of moisture which is best adapted for them, and choose our soil accordingly. Now the dryness or moisture of a soil depends upon two things; the nature and proportions of the earths which compose it, and the quantity of rain which falls upon it. Every soil contains at least three earths, silica, lime, and alumina, and sometimes also magnesia. The silica is always in a state of sand. Now soils retain moisture longer or

* Irish Trans. v. 160. † Veget. Stat. i. ‡ Mem. Par. 1772, 29.

§ The experiments of Braconnot, who has endeavoured to prove that water is the sole food of plants, are by no means decisive. See Ann. de Chim. lxi. 187. He raised plants on sand and metallic oxides by means of water, and found that the plants had all the usual vegetable, earthy, and alkaline constituents. But in experiments of that nature it is impossible to guard against every channel, by means of which these substances may have access to plants.

shorter according to the proportions of these earths. Those which contain the greatest quantity of sand retain it the shortest, and those which contain the greatest quantity of alumina retain it longest. The first is a dry, the second a wet soil. Lime and magnesia are intermediate between these two extremes: they render a sandy soil more retentive of moisture, and diminish the wetness of a clayey soil. It is evident, therefore, that by mixing together proper proportions of these four earths, we may form a soil of any degree of dryness and moisture that we please.

But whatever be the nature of the soil, its moisture must depend in general upon the quantity of rain which falls. If no rain at all fall, a soil, however retentive of moisture it be, must remain dry; and if rain were very frequently falling, the soil must be open indeed, if it be not constantly wet. The proportion of the different earths in a soil, therefore, must depend upon the quantity of rain which falls. In a rainy country, the soil ought to be open; in a dry country, it ought to be retentive of moisture. In the first, there ought to be a greater proportion of sand, in the second of clay.

2. That air is necessary for the vegetation of plants has been completely proved; and that a considerable portion at least of the carbonaceous matter which they contain is absorbed from the air, has been rendered probable by the experiments of chemical philosophers. Three articles which furnish nourishment to plants are supplied by the atmosphere; namely, *carbonic acid*, *oxygen*, and *moisture;* but it has been disputed how far plants are capable of absorbing carbonic acid, without the assistance of the soil on which they usually vegetate.

Mr Hassenfratz analyzed the bulbous roots of hyacinths, in order to discover the quantity of water, carbon, and hydrogen, which they contained; and by repeating the analysis on a number of bulbs, he discovered how much of these ingredients was contained in a given weight of the bulb. He analyzed also kidney-beans and cress seeds in the same manner. Then he made a number of each of these vegetate in pure water, taking the precaution to weigh them before hand, in order to ascertain the precise quantity of carbon which they contained. The plants being then placed, some within doors, and others in the open air, grew and flowered, but produced no seed. He afterwards dried them, collecting with care all their leaves and every other part which had dropped off during the course of vegetation. On submitting each plant to a chemical analysis, he found that the quantity of carbon which it contained, was somewhat less than the quantity which existed in the bulb or the seed from which the plant had sprung.*

These experiments have been repeated by Saussure with a very different result. Sprigs of *mentha piperita*, allowed to vegetate for some time in distilled water, nearly doubled the portion of carbon which they originally contained;† but when the same experiment was

* Ann. de Chim. xiii. 188. † Recherches Chimiques sur la Vegetation, p. 51.

repeated in a place where but little light had access, the carbon, instead of being increased, was somewhat diminished, as Hassenfratz had found. Hence it is probable, that the result obtained by Hassenfratz was owing to the want of light. Thus it cannot be doubted, that plants, even when they vegetate in pure water, are capable of absorbing nourishment from the air; but as plants in this situation cannot produce perfect seeds, and as they gradually decay and cease to vegetate, it is obvious that water and air alone are not sufficient.

3. The third, and only remaining source from which plants can draw their food, is the soil on which they grow. Now this soil consists of two parts; namely, *pure earths*, which constitutes its basis, and the *remains* of animals and vegetables applied as manure.

One use of the earthy part of the soil is to furnish a support for the plants, and to administer the proper quantity of water to them; but as all plants contain earthy and saline matters, and as these substances are constantly present, we cannot avoid considering them as in some measure constituting an essential part of plants. Now there is reason to believe that the proportion of earthy and saline matters in plants is considerably influenced by the soil on which they vegetate. Saussure made beans grow in three different situations. The first set was supported by distilled water; the second was planted in sand and supported by rain water; the third set was planted in a pot filled with mould, and placed in a garden. The ashes yielded by these different plants were to each other in the following proportions:—*

1	Those fed by distilled water .	3·9
2	Those fed by rain water .	7·5
3	Those growing in soil . .	12·0

Here the quantity of fixed matter yielded by the beans which had vegetated in soil was more than three times greater than what was obtained from those which had been fed solely by distilled water.

The same philosopher examined the ashes of various plants growing on a granitic and on a calcareous soil.† The plants which grew on the granitic soil contained a considerable proportion of silica and metallic oxides; those which grew in the calcareous, little or none of these bodies, but a greater proportion of calcareous earth than the granitic plants. Thus the pinus abies, the product of each of these soils, yielded the following proportions of fixed bodies:—

* Recherches Chimiques sur la Vegetation, p. 281.

† These soils were composed of the following ingredients:—

Granitic.		Calcareous.	
Silica . .	75·25	Carbonate of lime	98·000
Alumina . .	13·25	Alumina . .	0·625
Lime . .	1·74	Oxide of iron .	0·625
Iron and manganese	9·00	Petroleum .	0·025
	99·24		99·275

	Granitic.	Calcar.
Potash	3·60	15
Alkaline sulphates and muriates	4·24	
Carbonate of lime . . .	46·34	63
Carbonate of magnesia . .	6·76	0
Silica	13·49	0
Alumina	14·86	16
Metallic oxides . . .	10·52	0
	99·81	94*

Thus it cannot be doubted, that the proportion of earthy matter contained in plants is considerably influenced by the nature of the soil on which they grow; but whether plants derive the whole of these fixed principles from the soil, or whether they are capable of forming them to a certain extent by the unknown powers of vegetation, are questions not yet finally decided. The experiments of Saussure would lead us to believe, that all the earths found in plants are absorbed from the soil; while those of Schrader seem to prove, that a portion of them is formed by vegetation, even when plants are so situated that they can derive no fixed principle from the soil on which they grow.

The Berlin Academy proposed as a prize question, *To determine the earthy constituents of the different kinds of corn, and to ascertain whether these earthy parts are formed by the process of vegetation.* The prize was gained by Schrader, an apothecary in Berlin, and the result of his experiments was published by the Academy in 1800. He analyzed the seeds of *wheat*, *rye*, *barley*, and *oats*, and ascertained the portion of earth which each contains. He analyzed in the same manner rye-straw. After having in this manner determined the proportion of earth which these seeds contained, he endeavoured to make them grow in some medium which could not furnish any earthy ingredient whatever. For a long time his attempts were baffled, every substance tried containing less or more of earth, and being therefore improper. At last he found that sulphur, in the state of flowers, might be used with success, as it contained no earthy matter whatever, and as the seeds grew in it, and sent out their roots perfectly well, when it was properly moistened with water. The oxides of antimony and zinc were the substances which answered best after sulphur. The seeds, then, were planted in sulphur, placed in a garden at a distance from all dust, put into a box to which the light and the air had free access, but from which all dust and rain were carefully excluded, and they were watered with distilled water. The corn raised in this manner was found by Schrader to contain *more* earthy matter than had existed in the seeds from which it had grown.† Here, then, it would appear was the formation of earthy matter, unless we conceive that the air might have contained

* Phil. Mag. viii. 185. Jour. de Phys. lii. 27.

† Braconnot's experiments agree with those of Schrader, but they were not made with the same precautions. See Ann. de Chim. lxi. 187.

a sufficient quantity floating in it to furnish all that was found. Since the publication of his Prize Dissertation, Schrader has given to the public additional experiments on the same subject. In these he notices the trials of Saussure, and the results which were obtained from vegetables growing in calcareous and granitic soils; and particularly draws the attention of chemists to the fact ascertained by Saussure, that plants vegetating in a calcareous soil, which contained little or no silica, were yet found to yield a considerable portion of that earth.* Einhof likewise found in the ashes of a *pinus sylvestris*, which had grown in a soil that yielded no traces of lime, no less than 65 per cent. of that earth. He informs us also, that he has frequently observed the *lichen prunastri* and *ciliaris* encrusted in the months of August and September with a coat of carbonate of lime, when no lime was to be found in the neighbourhood, and when other plants were not encrusted in that manner.†

Saussure has observed very justly, that the absorption of earthy matter does not depend so much upon the earths which constitute the basis of the soil on which they grow, as upon the portion of earth held in solution in the liquid part of the soil. This observation will explain several of the facts above stated, but is by no means sufficient to set aside the experiments of Schrader, which go directly to prove that earths are formed by the processes of vegetation.

4. Besides earths, plants always contain a portion of saline matter. Those that grow at a distance from the sea contain potash, while sea-plants contain soda and common salt. Phosphate of lime is a constant ingredient, and phosphate of potash a very common one. Some plants contain peculiar salts. Thus nitrate of soda is usually present in barley, nitrate of potash in nettles and the sun-flower, &c. It appears from the experiments that have been made, that peculiar salts promote the vegetation of peculiar plants. Sea-plants require common salt, and languish in soils where it is not to be found. Borage, nettles, and pellitory, thrive only in soils which contain nitrate of lime or potash; gypsum promotes the vegetation of lucern and clover.‡

Salts then are not inactive; and when properly applied, they promote the growth of vegetables. In these cases they appear to be absorbed by the plants which they invigorate. Duhamel found that sea-plants made little progress in soils which contain no common salt. Bullion made seeds of sun-flower to grow in a sandy soil containing no trace of nitre. On examining the plants, no nitrate of potash could be detected in them, but the salt made its appearance as usual when the plants were watered with a weak nitrous solution.

From the experiments of Saussure, we learn that plants absorb saline solutions in very different proportions, and that in general those are absorbed in greatest quantity which are most injurious to

* Gehlen's Jour. iii. 538. † Ibid. 563. ‡ Saussure, Recherches, p. 264.

vegetation. He dissolved the following substances in water, in such proportions, that each solution contained $\frac{1}{100}$th part of its weight of the substance dissolved, except the last, which contained $\frac{1}{273}$th part:—

1 Muriate of potash
2 Muriate of soda
3 Nitrate of lime
4 Sulphate of soda effloresced
5 Muriate of ammonia
6 Acetate of lime
7 Sulphate of copper
8 Crystals of sugar
9 Gum arabic
10 Extract of soil.

Into each of these solutions he put plants of *polygonum persicaria*, or of *bidens cannabina*, furnished with their roots.

The polygonum grew for five weeks in the solutions of muriate of potash, nitrate of lime, muriate of soda, sulphate of soda, and extract of soil; and the roots increased in them as usual. It languished in the solution of sal ammoniac, and the roots made no progress. It died in eight or ten days in the solutions of gum and acetate of lime, and in less than three days in the solution of sulphate of copper.

When such a number of plants of polygonum were put into the solutions as to absorb one half of each in two days, the remaining half was found to have lost very different proportions of the salt which it had originally contained. Suppose the portion of salt originally in solution to be 100, the following table exhibits the quantity of each which had disappeared when one half of the liquid was absorbed:—

Muriate of potash	14·7
Muriate of soda	13·0
Nitrate of lime	4·0
Sulphate of soda	14·4
Muriate of ammonia	12·0
Acetate of lime	8·0
Sulphate of copper	47·0
Sugar	29·0
Gum	9·0
Extract of soil	5·0

The *bidens* absorbed pretty much the same proportions, but in general did not vegetate so long as the polygonum. In these trials, it was the sulphate of copper and the sugar that were absorbed in greatest abundance, and these were the substances which proved most injurious to the plant. Saussure explains this apparent anomaly by supposing that a portion of the roots were soon destroyed in these liquids, and that then they absorbed the solution indiscriminately.*

* Saussure, Recherches, p. 247, 261.

When various salts were dissolved at once in the same solutions, and plants made to vegetate in them, it was found that different proportions of the salts were absorbed. The following table exhibits the result of these trials, supposing, as before, the original weight of each salt to have been 100. Each solution contains $\frac{1}{100}$th part of its weight of each salt.

1	Sulphate of soda effloresced	11·7
	Muriate of soda . .	22·0
2	Sulphate of soda effloresced	12·0
	Muriate of potash . .	17·0
3	Acetate of lime . .	8·0
	Muriate of potash . .	33·0
4	Nitrate of lime . . .	4·5
	Muriate of ammonia . .	16·5
5	Acetate of lime . .	31·0
	Sulphate of copper . .	34·0
6	Nitrate of lime . .	17·0
	Sulphate of copper . .	34·0
7	Sulphate of soda . .	6·0
	Muriate of soda . .	10·0
	Acetate of lime . .	0·0
8	Gum	26·0
	Sugar	34·0

These experiments succeeded nearly equally with other plants, as *the mentha piperita* and the Scotch fir. When the roots were cut or removed, the plants absorbed all solutions indiscriminately. On examining the plants, the salts absorbed were found in them unaltered.

Thus it appears that plants do not absorb saline bodies indiscriminately. Saussure supposes that the difference depends rather upon the degree of liquidity which the solution possesses, than upon any discriminating power in the root. But if this were the case, it would be difficult to explain how so much greater a proportion of water should be absorbed than of the salt which it holds in solution.

5. Water, then, carbonic acid, and oxygen, and perhaps also earths and salts, constitute a part of the food of plants; but it is very clear that the whole food is not furnished by these substances. It is well known, that if vegetables be successively raised on the same ground, they at last exhaust it, or render it sterile; and to prevent this, farmers are obliged to supply their grounds annually with a quantity of manure. Without this manure, or some equivalent, plants cannot be made to thrive, or to perfect their seeds. Neither water, air, nor earths, nor salts, will prevent them from perishing. Giobert mixed together the four earths, silica, alumina, lime, and magnesia, in the proper proportions to constitute a fertile soil; and after moistening them with water, planted several vegetables

in them: but none of them grew well till he moistened his soil with water from a dunghill. Lampadius planted different vegetables in compartments of his garden, filled each with one of the pure earths, and watered them with the liquor which exuded from a dunghill. They all grew, notwithstanding the diversity of the soil; and each contained the usual earthy constituents of plants, notwithstanding the absence of these constituents from the soil.

It is not the earths which constitute a fertile soil, but the remains of animal and vegetable substances, and the proportion of these capable of being held in solution by water. It appears from the experiments of Mr Hassenfratz, that substances employed as manures produce effects in times proportioned to their degree of putrefaction; those substances which are most putrid producing the most speedy effects, and of course soonest losing their efficacy. Having manured two pieces of the same kind of soil, the one with a mixture of dung and straw highly putrefied, the other with the same mixture newly made, and the straw almost fresh, he observed, that during the first year, the plants which grew on the land manured with the putrefied dung produced a much better crop than the other: but the second year (no new dung being added), the ground which had been manured with the unputrefied dung produced the best crop; the same thing took place the third year, after which, both seemed to be equally exhausted.* Here it is evident that the putrefied dung acted soonest, and was soonest exhausted. It follows from this, that carbon only acts as a manure when in a particular state of combination; and this state, whatever it may be, is evidently produced by putrefaction. Another experiment of the same chemist renders this truth still more evident. He allowed shavings of wood to remain for about ten months in a moist place till they began to putrefy, and then spread them over a piece of ground by way of manure. The first two years this piece of ground produced nothing more than others which had not been manured at all; the third year it was better, the fourth year it was still better, the fifth year it reached its maximum of fertility; after which it declined constantly till the ninth, when it was quite exhausted.† Here the effect of the manure evidently depended upon its progress in putrefaction.

When vegetables are allowed to putrefy in the open air, they are converted in a loose black substance, well known under the name *vegetable mould*. On this mould plants grow with great vigour. It is the substance which renders newly cultivated lands in America, &c., so fertile. When exposed to the air, in the course of cultivation, it is gradually wasted and destroyed, and the lands are thus impoverished. This vegetable mould, therefore, is obviously one of the grand sources of the food of plants. It deserves, therefore, an accurate examination.

To Saussure and Einhof we are indebted for a chemical examination of its properties and constituents. Saussure employed in his

* Ann. de Chim. xiv. 57. † Ibid. xlv. 58.

experiments pure vegetable soil, which he procured either from the trunks of trees or from elevated rocks, where it was unmixed with any animal matter; and by passing it through a searce, he removed from it the remains of undecayed vegetables with which it was mixed.* By distilling 200 grains (French) of mould from the oak, he obtained the following products; while the same quantity of undecayed oak yielded him the following proportions of the same constituents:

	Mould.	Oak.
Carburetted hydrogen gas .	124 inches (French)	116
Carbonic acid . . .	34 . . .	29
Water, containing pyroligneous acid and pyrolignate of ammonia	53 grains (French)	80
Empyreumatic oil . .	10 . . .	13
Charcoal	51 . . .	41½
Ashes	8 . . .	0½

Nearly the same results were obtained by making similar experiments on other vegetables, and the mould which they yield when decayed. It appears from them, that the mould contains more charcoal, weight for weight, than the vegetables from which it proceeded. It yields also more ammonia, and therefore contains more azote.

Acids do not act powerfully on mould. Alcohol takes up a portion of extractive and resin. The fixed alkalies dissolve it almost completely, and ammonia is disengaged during the solution. Acids throw down a small portion of a brown combustible powder. Water dissolves a portion of extractive; but the quantity is small, especially from the mould of fertile soils. Ten thousand parts of water, left for five days on the mould of turf, were found to have dissolved only 26 parts of extract; and the same quantity, left on the soil of a field which bore a fine crop of wheat, was found to have dissolved but four parts. It appears from the experiments of Saussure, that a mould which yielded to boiling water, by repeated decoctions, $\frac{1}{11}$th of its weight of extract, did not produce so good an effect upon beans as a mould which contained only half that quantity of soluble matter. But when mould is deprived of its soluble part by boiling water, though its appearance is not altered, yet it does not support plants nearly so well as mould which has not been thus exhausted.†

The extract thus obtained from mould by Saussure, did not deliquesce when exposed to the air. When distilled it yielded carbonate of ammonia. It produced no change on vegetable blues. When reduced to the consistence of a syrup it had a sweet taste; it precipitated by exposure to the air, and became turbid when mixed with lime water, carbonate of potash, and most metallic solutions. Alcohol dissolves only a portion of it, and this part is very deliquescent.‡

From the experiments of Einhof, it appears that the extract ob-

* Recherches sur la Vegetation, p. 162. † Recherches, p. 170. ‡ Ibid. p. 174.

tained from mould possesses very nearly the properties of the *extractive principle.* The mould which he employed in his experiments was from the soil of a wood, and had been formed by the leaves of the trees and the putrefied herbs. It was black, firm, produced no change on vegetable blues, and contained no undecayed plants.* Water, in which this mould was boiled, was at first colourless; but by exposure to the air it acquired a brownish tint. The substance which is held in solution possessed exactly the characters of extractive.

Experiments upon vegetable mould have been made also by Braconnot. He found no portion of it soluble in water. His other results resembled those of Saussure. When an alkaline ley was boiled with mould a portion was dissolved. The residue had the exact appearance of pit coal.†

Besides this fertile vegetable mould, Einhof has examined another of a different nature, to which he has given the name of *acid vegetable mould.* It occurs in low-lying meadows and marshes, and the plants which grow upon it in these situations are the different species of *carex*, *juncus*, and *eriophorum.* It constitutes also the principal part of the mould in high-lying situations, and moors where the soil is covered with heath (*erica vulgaris.*) This mould is distinguished from the preceding by containing a notable portion of phosphoric and acetic acids, which give it the property of reddening vegetable blues. The extractive which it contains is chiefly insoluble in water.‡ This sour vegetable mould bears a considerable resemblance to peat, into which indeed it probably passes. Like it, peat contains a portion of phosphoric acid, and probably also of acetic acid, and an extractive readily soluble in alkalies, though but sparingly in water.§

Einhof has observed, that acid vegetable mould never occurs in those soils which abound in lime, and that it is counteracted and brought to the state of good mould by the action of lime and marl. It is clear that these manures will neutralize the acids, and thus enable the extractive, and other vegetable substances, to be acted upon by the atmosphere, to yield carbonic acid, and to assume those states which are proper for the nourishment of vegetables. It is probable that they act also directly upon the vegetable matter, and occasion decompositions favourable for vegetation. Hence the efficacy of lime when applied to peat moss, and to sour lands in general.

Upon the whole, then, it appears that plants are fed chiefly by that portion of vegetable matter which becomes soluble in water, and assumes the properties of extractive; that the quantity of it in soil must neither be too great nor too small; that the insoluble part of vegetable mould gradually assumes this state, either by the action of the atmosphere, or of earths or salts; that the presence of an

* Gehlen's Jour. vi. 373.
† Ann. de Chim. lxi. 191.
‡ Gehlen, vi. 379.
§ Einhof, Gehlen's Jour. iii. 400.

acid, by counteracting this change, injures the nourishing quality of vegetable mould; and that lime is serviceable, partly by neutralizing the acid, and partly by accelerating the decomposition of vegetable mould.

Animal manures probably supply similar materials with vegetable mould. They probably prevent the formation of acids, or neutralize them when formed: and likewise promote the decomposition and solubility of vegetable matter. The striking effects which animal manure produces on the growth of vegetables are well known; though it is not possible at present to point out the way in which they act. Two elaborate and ingenious sets of experiments on this subject have been published. The first, by Einhof and Thaer, consists of an examination of the excrements of black cattle;* and the second, by Berzelius, is upon the human excrementitious matter.† These add considerably to our knowledge of animal substances, but as they throw little light on the use of these matters as manures, it is unnecessary to give a detail in this place of the constituents of which they found them composed.

Such is the present state of our knowledge respecting the food of plants, as far as it is supplied by the soil in which they vegetate. It is probable that it is imbibed by the extremities of the roots only; for Duhamel observed, that the portion of the soil which is soonest exhausted is precisely that part in which the greatest number of the extremities of roots lies.‡ This shows us the reason why the roots of plants are continually increasing in length. By this means they are enabled, in some measure, to go in quest of nourishment. The extremities of the roots seem to have a peculiar structure adapted for the imbibing of moisture. If we cut off the extremity of a root, it never increases any more in length: therefore its use as a root has been in a great measure destroyed. But its sides send out fibres which act the part of roots, and imbibe food by their extremity. Nay, in some cases, when the extremity of a root is cut off, the whole decays, and a new one is formed in its place. This, as Dr Bell informs us, is the case with the hyacinth.§

The extremities of the roots contain no visible opening. Hence we may conclude that the food which they imbibe, whatever it may be, must be in a state of solution; while the absolute necessity of water renders it probable that water is the solvent. And, in fact, the carbonaceous matter in all active manures is in such a state of combination that it is soluble in water. All the salts which we can suppose to make a part of the food of plants, are more or less soluble in water. This is the case also with lime, whether it be pure or in the state of a salt; magnesia and alumina may be rendered so by means of carbonic acid gas; and Bergman, Macie, and Klaproth, have shown that even silica may be dissolved in water. We can see, therefore, in general, though we have no precise notions of the very

* Gehlen's Jour. iii. 276.
† Ibid. vi. 509.
‡ Physique des Arbres, iii. 239.
§ Manch. Mem. ii. 412.

combinations which are immediately imbibed by plants, that all the substances which form essential parts of that food *may* be dissolved in water.

CHAPTER V.

OF THE MOTION OF THE SAP.

Since the food of plants is imbibed by their roots in a fluid state, it must exist in plants in a fluid state; and unless it undergoes alterations in its composition just when imbibed, we may expect to find it in the plant unaltered. If there were any method of obtaining this fluid food from plants before it has been altered by them, we might analyse it, and obtain by that means a much more accurate knowledge of the food of plants than we can by any other method. This plan indeed must fail, provided the food undergoes alteration just when it is absorbed by the roots: but if we consider that when one species of tree is grafted upon another, each bears its own peculiar fruit, and produces its own peculiar substances, we can scarcely avoid thinking that the *great* changes at least which the food undergoes after absorption, are produced, not in the roots, but in other parts of the plant.

If this conclusion be just, the food of plants, after being imbibed by the roots, must go directly to those organs where it is to receive new modifications, and to be rendered fit for being assimilated to the different parts of the plant. There ought therefore to be certain juices continually ascending from the roots of plants; and these juices, if we could get them pure and unmixed with the other juices or fluids which the plant must contain, and which have been secreted and formed from these primary juices, would be, very nearly at least, the food as it was imbibed by the plant. Now, during the vegetation of plants, there actually is a *juice* continually ascending from their roots. This juice has been called the *sap*, the *succus communis*, or the *lymph* of plants.

The sap is most abundant during the spring. At that season, if a cut be made through the bark and part of the wood of some trees, the sap flows out very profusely. The trees are then said to *bleed*. By this contrivance any quantity of sap we think proper may be collected. It is not probable, indeed, that by this method we obtain the ascending sap in all its purity; it is no doubt mixed with the peculiar juices of the plant: but the less progress vegetation has made, the purer we may expect to find it; both because the peculiar juices must be in much smaller quantity, and because its quantity may be supposed to be greater. We should therefore examine the sap as early in the season as possible, and at all events before the leaves have expanded.

Though a number of experiments, as we have seen in the last Chapter, have been made upon the sap, they are not of such a nature as to throw much light upon the food absorbed by plants. Chemistry has not made such progress as to enable even the most expert analyst to separate and distinguish small quantities of the vegetable matter. It is even possible that the food, after it has been imbibed, may be, to a certain extent, modified and altered by the roots. In what manner this is done we cannot say, as we know very little about the vascular structure of the roots. We may conclude, however, that this modification is nearly the same in most plants: for one plant may be engrafted on another, and each continue to produce its own peculiar products; which could not be, unless the proper substances were conveyed to the digestive organs of all. There are several circumstances, however, which render the modifying power of the roots somewhat probable. It is even possible that the roots may, by some means or other, throw out again some part of the food which they have imbibed, as excrementitious. This has been suspected by several physiologists; and there are several circumstances which render it probable. It is well known that some plants will not vegetate well after others; and that some again vegetate unusually well when planted in ground where certain plants have been growing. These facts, without doubt, may be accounted for on other principles. If there be any excrementitious matter emitted by the roots, it is much more probable that this happens in the last stage of vegetation; that is to say, when the food, after digestion, is applied to the purposes which the root requires. Keiser considers the resinous and mucilaginous juices that are given out so abundantly by certain plants, as excrementitious matter. The turpentine emitted by the pine tribe, and the gum by the cherry tree, are, in his opinion, the excrements of these plants. In the same way the manna given out by the ash, and the ulmin by the elm are in the same predicament.

Mr Knight, to whose ingenious and important experiments and observations vegetable physiology lies under so many obligations, has rendered it extremely probable that the sap, as it ascends, is mixed with a quantity of matter, previously deposited in the alburnum for that purpose, and ready prepared to be assimilated to the different vegetable organs.* According to him, plants, after they have attained their full growth, are employed during the latter part of summer in preparing food for the expanding of the buds and blossoms in the succeeding spring. This food, when prepared, is deposited in the alburnum. Here it continues during the winter; and in next spring, mixing with the ascending sap, it affords nourishment to the buds and leaves. This ingenious opinion Mr Knight has supported by experiments and observations, sufficient, I think, to establish its truth. It constitutes a very important step in vegetable physiology, as it enables us to explain many circum-

* On the State in which the True Sap of Trees is deposited during Winter. Phil. Trans. 1805.

stances in a satisfactory manner that appeared formerly altogether anomalous.

He ascertained, by experiments, that the sap increases in density as it ascends towards the leaves. Sap extracted from the sycamore, close to the ground, was of the specific gravity of 1·004; while that which flowed out at the height of seven feet was 1·008, and at the height of twelve feet 1·012. The sap of the birch was somewhat lighter, but its comparative increase of density, according to its height, was the same. When extracted near the ground, the sap, both of the sycamore and birch, was nearly tasteless; but it became sensibly sweet at some height, and the sweetness increased with the distance from the ground. Thus it appears, that the quantity of vegetable matter in sap increases as it flows towards the leaves; a direct proof that it imbibes and mixes with something during its passage. That this matter was lodged in the alburnum was rendered probable by comparing with each other the alburnum in winter and in summer. For, if nutriment be laid up in the alburnum in winter, and employed in summer for the purposes of vegetation, it is obvious that the alburnum during winter ought to be denser, and ought to yield more extract to water, than the same substance in summer: both of which Mr Knight found to be the case. Oak poles, of the same age, and growing from the same stool, were felled, partly in December and partly in May. They were placed in the same situation, and dried for seven weeks by a fire. The specific gravity of the winter felled wood was 0·679, of the summer 0·609. When the alburnum alone was weighed, the specific gravity of the winter felled was 0·583; of the summer felled 0·533. One thousand grains of each being mixed with six ounces of boiling water, and left to macerate for 24 hours, the winter felled infusion was much deeper coloured than the other. Its specific gravity was 1·002; while that of the summer felled infusion was 1·001. This deposition of nutritious matter explains why the alburnum of trees felled in winter is much more solid and valuable than the alburnum of trees felled in summer.

The sap, as Dr Hales has shown us, ascends with a very considerable force. It issued during the bleeding season with such impetuosity from the cut end of a vine branch, that it supported a column of mercury 32½ inches high.*

Now, what is the particular channel through which the sap ascends, and what is the cause of the force with which it moves? These are questions which have excited a great deal of the attention of those philosophers who have made the physiology of vegetables their particular study; but the examination of them is attended with so many difficulties that they are very far from being decided.

It is certain that the sap flows from the roots towards the summit of the tree. For if in the bleeding season a number of openings be

* Veg. Stat. i. 105.

made in the tree, the sap begins first to flow from the lowest opening, then from the lowest but one, and so on successively, till at last it makes its appearance at the highest of all; and when Duhamel and Bonnet made plants vegetate in coloured liquors, the colouring matter, which was deposited in the wood, appeared first in the lowest part of the tree, and gradually ascended higher and higher, till at last it reached the top of the tree, and tinged the very leaves.

It seems certain too that the sap ascends through the wood, and not through the bark of the tree: for a plant continues to grow even when stripped of a great part of its bark; which could not happen if the sap ascended through the bark. When an incision, deep enough to penetrate the bark, and even part of the wood, is carried quite round a branch, provided the wound be covered up from the external air, the branch continues to vegetate as if nothing had happened; which could not be the case if the sap ascended between the bark and the wood. It is well known, too, that in the bleeding season little or no sap can be got from a tree unless our incision penetrate deeper than the bark.

These conclusions have been confirmed by the experiments made by Coulomb and Knight. Coulomb observed that no sap ever flows from the poplar till the tree be cut nearly to the centre.* Mr Knight observed that coloured infusions always pass through the alburnum, and that whenever the alburnum is cut through, the plant dies.†

As the sap is never found in the parenchyma, it must of necessity be confined in particular vessels; for if it were not, it would undoubtedly make its appearance there. Now, what are the vessels through which the sap ascends?

Grew and Malpighi, the first philosophers who examined the structure of plants, took it for granted that the woody fibres were tubes, and that the sap ascended through them. For this reason they gave these fibres the name of *lymphatic vessels*. But they were unable, even when assisted by the best microscopes, to detect any thing in these fibres which had the appearance of a tube; and succeeding observers have been equally unsuccessful. The conjecture therefore of Malpighi and Grew, about the nature and use of these fibres, remains totally unsupported by any proof. Duhamel has even gone far to overturn it altogether: for he found that those woody fibres are divisible into smaller fibres, and these again into still smaller; and even, by the assistance of the best microscopes, he could find no end of this subdivision.‡ Now, granting these fibres to be vessels, it is scarcely possible, after this, to suppose that the sap really moves through tubes, whose diameters are almost infinitely small.

It is probable, from the most careful microscopical observations which have been made, that the intercellular canals are the channels through which the sap ascends.

* Jour. de Phys. xlix. 392. † Phil. Trans. 1801, p. 336.

‡ Physique des Arbres, i. 57.

But by what powers is the sap made to ascend in these vessels? and not only to ascend, but to move with very considerable force; a force, as Hales has shown, sufficient to overcome the pressure of 43 feet perpendicular of water?*

Grew ascribed this phenomenon to the levity of the sap; which, according to him, entered the plant in the state of a very light vapour. But this opinion will not bear the slightest examination. Malpighi supposed that the sap was made to ascend by the contraction and dilatation of the air contained in the air-vessels. But even were we to grant that the tracheæ are air vessels, the sap, according to this hypothesis, could only ascend when a change of temperature takes place; which is contrary to fact. And even if we were to waive every objection of that kind, the hypothesis would not account for the circulation of the sap, unless the sap vessels be provided with valves. Now, the experiments of Hales and Duhamel show that no valves can possibly exist in them: for branches imbibe moisture nearly equally by either end; and consequently the sap moves with equal facility both upwards and downwards, which it could not do were there valves in the vessels. Besides, it is known, from many experiments, that we may convert the roots of a tree into the branches, and the branches into the roots, by covering the branches with earth, and exposing the roots to the air.† Now, this would be impossible if the sap vessels were provided with valves. The same remarks overturn the hypothesis of M. de la Hire, which is merely that of Malpighi, expressed with greater precision, and with a greater parade of mechanical knowledge. Like Borelli, he placed the ascending power of the sap in the parenchyma. But his very experiments, had he attended to them with care, would have been sufficient to show the imperfection of his theory.

The greater number of philosophers (for it is needless to mention those who, like Perrault, had recourse to fermentation, nor those who introduced the weight of the atmosphere) have ascribed the motion of the sap to *capillary attraction*.

There exists an attraction between many solid bodies and liquids; in consequence of which, if these solid bodies be formed into small tubes, the liquid enters them, and rises in them to a certain height. But this is perceptible only when the diameter of the tube is very small. Hence the attraction has been denominated *capillary*. We know that there is such an attraction between vegetable fibres and watery liquids; for such liquids will ascend through dead vegetable matter. It is highly probable, therefore, that the food of plants enters the roots, in consequence of the capillary attraction which

* Veget. Stat. i. 107.

† Mr Knight has shown that the inverted shoots by no means grow so well as when in their natural position; and has even made it probable, that the vessels of the bark are furnished with valves, or with something equivalent. But no evidence has been adduced to induce us to believe, that this is the case with the sap vessels.—See his Observations on the Motion of the Sap of Trees. Phil. Trans. 1804.

subsists between the sap vessels and the liquid imbibed. This species of attraction, then, will account perfectly well for the entrance of moisture into the mouths of the sap vessels: but will it account also, as some have supposed, for the ascent of the sap, and for the great force with which it ascends?

The nature and laws of capillary attraction have been very much overlooked by philosophers. But we know enough concerning it to enable us to decide the present question. It consists in a certain attraction between the particles of the liquid and of the tube. It has been demonstrated, that it does not extend, or at least that it produces no sensible effect, at greater distances than $\frac{1}{1000}$th part of an inch. It has been demonstrated, that the water ascends, not by the capillary attraction of the whole tube, but of a slender film of it; and Clairaut has shown that this film is situated at the lowermost extremity of the tube.* This film attracts the liquid with a certain force; and if this force be greater than the cohesion between the particles of the liquid, part enters the tube, and continues to enter, till the quantity above the attracting film of the tube just equals, by its weight, the excess of the capillary attraction between the tube and the liquid above the cohesion of the liquid. The quantity of water, therefore, in the tube is pretty nearly the measure of this excess; for the attracting film is probably very minute.

It has been demonstrated, that the heights to which liquids rise in capillary tubes are inversely as the diameter of the tube. Consequently the smaller the diameter of the tube, the greater is the height to which the liquid will rise. But the particles of water are not infinitely small; therefore, whenever the diameter of the tube is diminished beyond a certain size, water cannot ascend in it, because its particles are now larger than the bore of the tube. Consequently the rise of water in capillary tubes must have a limit: if they exceed a certain length, how small soever their bore may be, water will either not rise to the top of them, or it will not enter them at all. We have no method of ascertaining the precise height to which water would rise in a capillary tube, whose bore is just large enough to admit a single particle of water. Therefore we do not know the limit of the height to which water may be raised by capillary attraction. But whenever the bore is diminished beyond a certain size, the quantity of water which rises in it is too small to be sensible. We can easily ascertain the height which water cannot exceed in capillary tubes before this happens; and if any person calculate, he will find that this height is not nearly equal to the length of the sap vessels of many plants. But besides all this, we see in many plants very long sap vessels, of a diameter too large for a liquid to rise in

* The action of all the other films, of which the tube is composed, on the water, as far as it is measured by its effect, is nothing at all. For every particle of water in the tube (except those attracted by the undermost film) is attracted upwards and downwards by the same number of films: it is therefore precisely in the same state as if it were not attracted at all.

them a single foot by capillary attraction, and yet the sap rises in them to very great heights.

If any person says that the sap vessels of plants gradually diminish in diameter as they ascend; and that, in consequence of this contrivance, they act precisely as an indefinite number of capillary tubes, one standing upon another, the inferior serving as a reservoir for the superior—I answer, that the sap may ascend by that means to a considerable height: but certainly not in any greater quantity than if the whole sap vessel had been precisely of the bore of its upper extremity; for the quantity of sap raised must depend upon the bore of the upper extremity, because it must all pass through that extremity.

But farther, if the sap moved only in the vessels of plants by capillary attraction, it would be so far from flowing out at the extremity of a branch, with a force sufficient to overcome the pressure of a column of water 43 feet high, that it could not flow out at all. It would be impossible in that case for any such thing as the bleeding of trees ever to happen.

If we take a capillary tube, of such a bore that a liquid will rise in it six inches, and after the liquid has risen to its greatest height, break it short three inches from the bottom, none of the liquid in the under half flows over. The tube, thus shortened, continues indeed full, but not a single particle of liquid ever escapes from it. And how is it possible for it to escape? The film, at the *upper* extremity of the tube, must certainly have as strong an attraction for the liquid as the film at the *lower* extremity. As part of the liquid is within its attracting distance, and as there is no part of the tube above to counterbalance this attraction, it must of necessity attract the liquid nearest it, and with a force sufficient to counterbalance this attraction of the undermost film, how great soever we may suppose it. Of course no liquid can be forced up, and consequently none can flow out of the tube. Since, then, the sap *flows out* at the upper extremity of the sap vessels of plants, we are absolutely certain that it does not ascend in them merely by its capillary attraction, but that there is some other cause.

It is impossible, therefore, to account for the motion of the sap in plants by any mechanical or chemical principles whatever; and he who ascribes it to these principles has not formed to himself any clear or accurate conception of the subject. We know indeed that heat is an agent; for Dr Walker found that the ascent of the sap is much promoted by heat, and that after it had begun to flow from several incisions, cold made it give over flowing from the higher orifices while it continued to flow at the lower.* But this cannot be owing to the dilating power of heat; for unless the sap vessels of plants were furnished with valves, dilatation would rather retard than promote the ascent of the sap.

We must, therefore, ascribe it to some other cause: the vessels

* Edin. Trans. i.

themselves must certainly act. Many philosophers have seen the necessity of this, and have accordingly ascribed the ascent of the sap to *irritability*. But the first person who gave a precise view of the manner in which the vessels probably act was Saussure. He supposes that the sap enters the open mouths of the vessels at the extremity of the roots; that these mouths then contract, and by that contraction propel the sap upwards; that this contraction gradually follows the sap, pushing it up from the extremity of the root to the summit of the plant. In the mean time the mouths are receiving new sap, which in the same manner is pushed upwards.* Whether we suppose the contraction to take place precisely in this manner or not, we can scarcely deny that it must take place; but by what means it is impossible at present to say. The agents cannot precisely resemble the muscles of animals; because the whole tube, however cut or maimed, still retains its contracting power, and because the contraction is performed with equal readiness in every direction.† It is evident, however, that they must be the same in kind. Perhaps the particular structure of the vessels may fit them for their office. Does ring after ring contract its diameter? The contracting agents, whatever they are, seem to be excited to act by some stimulus communicated to them by the sap. This capacity of being excited to action is known in physiology by the name of *irritability;* and there are not wanting proofs that plants are possessed of it. It is well known that different parts of plants move when certain substances act upon them. Thus the flowers of many open at sunrise, and close again at night. Linnæus has given us a list of these plants. Des Fontaines has shown that the stamina and antheræ of many plants exhibit distinct motions.‡ Dr Smith has observed, that the stamina of the barberries are thrown into motions when touched.§ Roth has ascertained that the leaves of the *drosera longifolia* and *rotundifolia* have the same property. Mr Coulomb, too, who has adopted the opinion that the motion of the sap in plants is produced by the contraction of vessels, has even made a number of experiments in order to show this contraction. But the fact is, that every one has it in his power to make a decisive experiment. Simply cutting a plant, the *euphorbia peplis* for instance, in two places, so as to separate a portion of the stem from the rest, is a complete demonstration that the vessels actually do contract. For whoever makes the experiment, will find that the

* Encycl. Meth. Phys. Veget. p. 267.

† Mr Knight thinks it probable that the sap is propelled by the contraction and expansion of what is called by carpenters the *silver grain* of the wood, between the lamina of which the vessels run. (Phil. Trans. 1801, p. 344.) By *silver grain* is meant those thin longitudinal fibres, diverging in every direction from the pith, and composed of the lymphatic vessels of Grew and Malpighi. I do not see how the contraction of these laminæ could propel the sap through the sap vessel, destitute as they are of valves, unless it were a contraction precisely similar to what Saussure supposed to take place in the sap vessels.

‡ Mem. Par. 1787. § Phil. Trans. lxxviii.

milky juice of that plant flows out at both ends so completely, that if afterwards we cut the portion of the stem in the middle no juice whatever appears. Now it is impossible that these phenomena could take place without a contraction of the vessels; for the vessels in that part of the stem which has been detached cannot have been more than full; and their diameter is so small, that if it were to continue unaltered, the capillary attraction would be more than sufficient to retain their contents, and consequently not a drop flow out. Since, therefore, the whole liquid escapes, it must be driven out forcibly, and consequently the vessels must contract.

It seems pretty plain, too, that the vessels are excited to contract by various stimuli; the experiments of Coulomb and Saussure render this probable, and an observation of Dr Smith Barton makes it next to certain. He found that plants growing in water vegetated with much greater vigour, provided a little camphor was thrown into the water.*

CHAPTER VI.

OF THE FUNCTIONS OF THE LEAVES.

It has been ascertained that the sap ascends to the leaves, that it there undergoes certain alterations, and is converted into another fluid called the *succus proprius*, *peculiar juice*, or *true sap*; which, like the blood in animals, is afterwards employed in forming the various substances found in plants. Now, the changes which the sap undergoes in the leaves, provided we can trace them, must throw a great deal of light upon the nature of vegetation. These changes are produced in part during the day, in part during the night. Now, as the functions of the leaves during the day are very different from what they are during the night, it will be proper to consider them separately.

I. No sooner has the sap arrived at the leaves, than a great part of it is thrown off by evaporation.

1. The quantity thus perspired bears a very great proportion to the moisture imbibed. Dr Woodward found that a sprig of mint, weighing 27 grains, in 77 days imbibed 2558 grains of water, and yet its weight was only increased 15 grains; therefore it must have given out 2543 grains. The same experiment was repeated by this philosopher on other plants; the following table exhibits the result:†

* Ann. de Chim. xxiii. 63. † Phil. Trans. 1699, xxix. 193.

Plants and Water.	Weight. When put in.	Weight. When taken out.	Gain in 77 days.	Water wasted.
	gr.	gr.	gr.	gr.
Spearmint in spring water . .	27	42	15	2558
Spearmint in rain water . .	28½	45¾	17½	3004
Spearmint in Thames water . .	28	54	26	2493
Common nightshade in spring water	49	106	57	3708
Latharis in spring water . .	98	101½	3½	2501

These experiments demonstrate the great quantity of matter which is constantly leaving the plant. Dr Hales found that a cabbage transmitted daily a quantity of moisture equal to about half its weight; and that a sun-flower, three feet high, transmitted in a day 1 lb. 14 oz. avoirdupois.* He showed, that the quantity of transpiration in the same plant was proportional to the surface of the leaves, and that when the leaves were taken off, the transpiration nearly ceased.† By these observations, he demonstrated that the leaves are the organs of transpiration. He found, too, that the transpiration was nearly confined to the day, very little taking place during the night;‡ that it was much promoted by heat, and stopped by rain and frost:§ and Millar,‖ Guettard,¶ and Sennebier, have shown that the transpiration is also very much promoted by sunshine. From Guettard's experiments, it appears that the amount of the transpiration considerably exceeds the amount found by Hales. The *cornus* with white fruit transpired daily about twice its own weight of moisture.

The quantity of moisture imbibed by plants depends very much upon what they transpire; the reason is evident: when the vessels are once filled with sap, if none be carried off, no more can enter; and, of course, the quantity which enters must depend upon the quantity emitted.

2. In order to discover the nature of the transpired matter, Hales placed plants in large glass vessels, and by that means collected a quantity of it.** He found that it resembled pure water in every particular, excepting only that it sometimes had the odour of the plant. He remarked, too, as Guettard and Duhamel did after him, that when kept for some time it putrefied, or at least acquired a stinking smell. Sennebier subjected a quantity of this liquid to a chemical analysis.

He collected 13030 grains of it from a vine during the months of May and June. After filtration he gradually evaporated the whole to dryness. There remained behind two grains of residuum. These two grains consisted of nearly ½ grain of carbonate of lime, $\frac{1}{12}$ grain

* Veget. Stat. i. 5 and 15. † Veget. Stat. p. 30.
‡ Ibid. p. 5. § Ibid. p. 27. and 48. ‖ Ibid. p. 22.
¶ Mem. Par. 1748, p. 569. ** Veget. Stat. i. 49.

of sulphate of lime, ½ grain of matter soluble in water, and having the appearance of gum, and ½ grain of matter which was soluble in alcohol, and apparently resinous. He analysed 60768 grains of the same liquid, collected from the vine during the months of July and August. On evaporation, he obtained 2⅛ grains of residuum, composed of ¾ grain of carbonate of lime, ¼ grain of sulphate of lime, ½ grain of mucilage, and ½ grain of resin. The liquid transpired by the *aster Novæ Angliæ* afforded precisely the same ingredients.*

3. Sennebier attempted to ascertain the proportion which the liquid transpired bore to the quantity of moisture imbibed by the plant. But it is easy to see that such experiments are liable to too great uncertainties to be depended on. His method was as follows: he plunged the thick end of the branch on which he made the experiment into a bottle of water, while the other end, containing all its leaves, was thrust into a very large glass globe. The apparatus was then exposed to the sunshine. The quantity imbibed was known exactly by the water which disappeared from the bottle, and the quantity transpired was judged of by the liquid which condensed and trickled down the sides of the glass globe. The following table exhibits the result of his experiments:

Plants.	Imbibed.	Perspired.	Time.
Peach	100 gr.	35 gr.	—
Ditto	210	90	—
Ditto	220	120	—
Mint	200	90	2 days
Ditto	575	120	10
Rasp	725	560	2
Ditto	1232	765	2
Peach	710	295	1
Apricot	210	180	1

In some of his experiments no liquid at all was condensed. Hence it is evident that the quantity of matter transpired cannot be deduced from these experiments. The mouth of the glass globe does not seem to have been accurately closed; the air within it communicated with the external air; consequently the quantity condensed must have depended entirely upon the state of the external air, the heat, &c.

4. The first great change, then, which takes place upon the sap after it arrives at the leaves, is the evaporation of a great part of it; consequently what remains must be very different in its proportions from the sap. The leaves seem to have particular organs adapted for throwing off part of the sap by transpiration; for the experiments of Guettard,† Duhamel,‡ and Bonnet,§ show that it is performed chiefly by the upper surfaces of leaves, and may be nearly stopped altogether by varnishing that surface.

* Encyc. Meth. Phys. Veget. 287.
† Mem. Par. 1749, p. 265.
‡ Physique des Arbres, i. 158.
§ Traite des Feuilles, 1. Mem.

The leaves of plants become gradually less and less fit for this transpiration; for Sennebier found that when all other things are equal, the transpiration is much greater in May than in September.* Hence the reason that the leaves are renewed annually. Their organs become gradually unfit for performing their functions, and therefore it is necessary to renew them. Those trees which retain their leaves during the winter were found by Hales and succeeding physiologists to transpire less than others. It is now well known that these trees also renew their leaves.

II. Leaves have also the property of absorbing carbonic acid gas from the atmosphere.

1. We are indebted for this very important discovery to the experiments of Dr Priestley. It had been long known that when a candle has been allowed to burn out in any quantity of air, no candle can afterwards be made to burn in it. In the year 1771, Dr Priestley made a sprig of mint vegetate for ten days in contact with a quantity of such air: after which he found that a candle would burn in it perfectly well.† This experiment he repeated frequently, and found that it was always attended with the same result. According to the opinion at that time universally received, that the burning of candles rendered air impure by communicating phlogiston to it, he concluded from it, that plants, while they vegetate, absorb phlogiston.

Carbonic acid gas was at that time supposed to contain phlogiston. It was natural, therefore, to suppose that it would afford nourishment to plants, since they had the property of absorbing phlogiston from the atmosphere. Dr Percival had published a set of experiments, by which he endeavoured to show that this was actually the case.

These experiments induced Dr Priestley, in 1776, to consider the subject with more attention. But as, in all the experiments which he made, the plants confined in carbonic acid gas very soon died, he concluded that carbonic acid gas was not a food, but a poison to plants.‡ Mr Henry of Manchester was led, in 1784, probably by the contrariety of these results, to examine the subject. His experiments, which were published in the *Manchester Transactions*,§ perfectly coincided with those of Dr Percival. For he found that carbonic acid gas, so far from killing plants, constantly promoted their growth and vigour. Meanwhile Mr Sennebier was occupied at Geneva with the same subject; and he published the result of his researches in his *Memoires Physico-Chymiques* about the year 1780. His experiments showed, in the clearest manner, that carbonic acid gas is used by plants as food. The same thing was supported by Ingenhousz in his second volume. The experiments of Saussure junior, published in 1797, have at last put the subject beyond the reach of dispute. From a careful comparison of the experiments of these philosophers, it will not be difficult for

* Encyc. Meth. Veget. 285.
† On Air, iii. 251.
‡ On Air, i. 100.
§ Vol. ii. 341.

us to discover the various phenomena, and to reconcile all the seeming contradictions which occur in them. The facts are as follows:—

2. Plants will not vegetate in an atmosphere of pure carbonic acid, nor if their atmosphere contains $\frac{3}{4}$ths of its bulk of that gas. They vegetate in the sun when confined in atmospheres containing $\frac{1}{2}$, $\frac{1}{4}$th, or $\frac{1}{8}$th, of that gas, and the vegetation improves as the quantity of gas diminishes. When the atmosphere contains only $\frac{1}{12}$th of carbonic acid gas, plants grow in it considerably better in the sun, than when placed in an atmosphere of common air; but when plants are placed in the shade, the presence of carbonic acid always injures their vegetation instead of promoting it.*

3. Mr Saussure has shown, that plants will not vegetate in the sun when totally deprived of carbonic acid gas. They vegetate indeed well enough in air which has been previously deprived of carbonic acid gas; but when a quantity of lime was put into the glass vessel which contained them, they no longer continued to grow, and the leaves in a few days fell off.† The air, when examined, was found to contain no carbonic acid gas. The reason of this phenomenon is, that plants (as we shall see afterwards) have the power of forming and giving out carbonic acid in certain circumstances; and this quantity is sufficient to continue their vegetation for a certain time. But if this new formed gas be also withdrawn, by quicklime for instance, which absorbs it the instant it appears, the leaves droop, and refuse to perform their functions.‡ Carbonic acid gas, then, applied to the leaves of plants, is *essential* to vegetation.

4. The direct contrary takes place in the shade. Plants not only continue to vegetate when deprived of all carbonic acid by means of lime; but they flourish more than if it were allowed to remain.§

5. Dr Priestley, to whom we are indebted for many of the most important facts relative to vegetation, observed, in the year 1778, that plants, in certain circumstances, emitted oxygen gas;‖ and Ingenhousz very soon after discovered that this gas is emitted by the *leaves* of plants, and only when they are exposed to the bright light of day. His method was to plunge the leaves of different plants into vessels full of water, and then expose them to the sun, as Bonnet, who had observed the same phenomenon, though he had given a wrong explanation of it, had done before him. Bubbles of oxygen gas very soon detached themselves from the leaves, and

* Saussure, Recherches Chimiques sur la Vegetation, p. 30.

† Ann. de Chim. xxiv. 145, 148.

‡ Braconnot has rendered it probable, that in this experiment it was not the absence of carbonic acid, but the deleterious effects of the lime that killed the plants in Saussure's experiments. Ann. de Chim. lxi. 187.

§ Saussure, Recherches, p. 36. M. Macaire has found that chlorine, nitric acid, nitrous gas, sulphuretted hydrogen, and muriatic acid do not injure plants during the day; but destroy them during the night. Mem. Hist. Nat. of Geneva, v. 283.

‖ On Air, iii. 284.

were collected in an inverted glass vessel.* He observed, too, that it was not a matter of indifference what kind of water was used. If the water, for instance, had been previously boiled, little or no oxygen gas escaped from the leaves; river water afforded but little gas; but pump-water was the most productive of all.†

Sennebier proved, that if the water be previously deprived of all its air by boiling, the leaves do not emit a particle of air; that those kinds of water which yield most air contain in them the greatest quantity of carbonic acid gas; that leaves do not yield any oxygen when plunged in water totally destitute of carbonic acid gas; that they emit it abundantly when the water, rendered unproductive by boiling, is impregnated with carbonic acid gas; that the quantity of oxygen emitted, and even its purity, is proportional to the quantity of carbonic acid gas which the water contains; that water impregnated with carbonic acid gas gradually loses the property of affording oxygen gas with leaves; and that whenever this happens, all the carbonic acid gas has disappeared; and on adding more carbonic acid gas the property is renewed.‡ These experiments prove, in a most satisfactory manner, that the oxygen gas which the leaves of plants emit depends upon the presence of carbonic acid gas; that the leaves absorb carbonic acid gas, decompose it, give out the oxygen, and retain the carbon. They have been confirmed by the experiments of Dr Woodhouse. To this gentleman likewise we are indebted for a very full set of experiments on the quantity of gas produced by exposing different plants in water to sunshine for given times.§

Saussure has shown that green fruits produce the same changes on air as leaves do, only they do not act with so much energy. Carbonic acid is absorbed, and oxygen gas given out in the sun; while carbonic acid is emitted, and oxygen absorbed in the shade.‖

6. Sennebier has ascertained, that the decomposition of the carbonic acid takes place in the parenchyma. He found that the epidermis of a leaf would, when separated, give out no air, neither would the nerves in the same circumstances; but upon trying the parenchyma, thus separated from its epidermis and part of its nerves, it continued to give out oxygen as before.¶

That the decomposition is performed by peculiar organs is evident from an experiment of Ingenhousz. Leaves cut into small pieces continued to give out oxygen as before; but leaves pounded in a mortar lost the property entirely. In the first state, the peculiar structure remained; in the other it was destroyed. Certain experiments of Count Rumford, indeed, may seem incompatible with this conclusion; and they will naturally occur to the reader as an objection. He found that dried leaves of black poplar, fibres of raw silk,

* Ingenhousz on Veget. i. 15, &c. † Ibid. p. 33.
‡ Encyc. Method. Physiol. Veget. 181.
§ See Nicholson's Jour. ii. 154, and Ann. de Chim. xliii. 200.
‖ Ann. de Chim. et de Phys. xix. 143, 225.
¶ Encyc. Method. Physiol. Veget. 180.

and even glass, when plunged into water, gave out oxygen gas by the light of the sun; but when Sennebier repeated these experiments, they did not succeed.* It was probably the air contained in the water which separated in the Count's experiments.†

7. From the experiments of Saussure, we learn that the quantity of carbonic acid thus absorbed and decomposed varies greatly in different plants, even when placed in the same circumstances. The *lythrum salicaria* was found to absorb 7 or 8 times its bulk of this gas in a day; while the *cactus opuntia*, and other fleshy-leaved plants, did not absorb above a fifth of that quantity. The portion absorbed, according to Saussure, depends upon the surface of the plant; and therefore thin-leaved plants must absorb more than those that have fleshy leaves.‡

8. It does not appear that the whole of the oxygen contained in the carbonic acid absorbed is emitted again by the plant. A considerable portion of it seems to be retained. This, at least, is the result which follows from a set of experiments made by Saussure on purpose to ascertain the point. He mixed carbonic acid with common air, in such a proportion that it occupied $7\frac{1}{2}$ hundredths of the mass. Jars, standing over mercury (covered with a thin film of water), were filled with this mixture; and plants of *vinca minor*, growing in a small vessel filled with water, were introduced into the jar. These plants, thus placed, were exposed for six successive days to the sun, from five in the morning to eleven, while the temperature of the air was 70°; during all which time they vegetated with great vigour. The bulk of the air in the jar was not sensibly altered. No carbonic acid could be detected in it. The proportion of oxygen was $24\frac{1}{2}$ per cent. The following table exhibits the proportion of the constituents of this air, in French cubic inches, when put into the jar, and after the plants had vegetated in it six days.§

	When put in.	When taken out.
Azote	211·92	218·95
Oxygen . . .	56·33	71·05
Carbonic acid . .	21·75	0·00
	290·00	290·00

Thus the whole 21·75 inches of carbonic acid were absorbed; but the oxygen emitted was only 14·72 inches, whereas the whole oxygen in the carbonic acid would have amounted to 21·75 inches. The difference, amounting to about seven inches, was made up by a quantity of azote, which had been given out by the plants along with the oxygen. The following table exhibits the result of similar ex-

* Ann. de Chim. i. 115.

† Dr Woodhouse tried the experiments with filaments of asbestus, baked horse-hair, cotton, pannicles of rhus cotinus, cotton of the asclepias syriaca, hairy plumes of clematis crispa, spikes of panicum glaucum, charcoal powder; each of these, he affirms, yielded in water a little oxygen gas, but less pure than the leaves of plants. Nicholson's Jour. ii. 158.

‡ Recherches Chimiques, p. 56.

§ Ibid. p. 40.

periments, made by this philosopher, on other plants. All the numbers denote cubic inches.

Plants.	Bulk of plants.	Air in jar.	Carbonic acid, per cent. in ditto.	Duration of experiment.	Carbonic acid, per cent. in residuary air.	Oxygen per cent. in ditto.	Carbonic acid absorbed.	Gas emitted.		Diminution of bulk of residuary gas.
								Oxygen.	Azote.	
				Days.						
Mentha aquatica	0·5	328	7·5	10	2·5	23·5	15·6	11·26	4·34	0
Lythrum salicaria	0·14	75	10	7	0	27·25	7·5	6·13	1·1	0·5
Pinus Genevensis	0·5	280	7	18	1·5	24·5	15·5	12·5	1	2
Cactus opuntia	1·1	155	10		4	24	9·3	6·4	2·9	0

9. Thus it appears that plants, when exposed to the light, absorb carbonic acid, decompose it, and throw out again the greatest part of the oxygen of this gas mixed (it would seem) with a little *azote.** It is probable that plants, by this process, acquire a considerable part of the carbonaceous matter which they contain; for if we compare the quantity of carbon contained in plants vegetating in the dark, where this process does not go on, with the quantity which those plants contain which vegetate in the usual manner, we shall perceive a very conspicuous difference. Chaptal found that a byssus, which was vegetating in the dark, contained only $\frac{1}{89}$th of its weight of carbonaceous matter; but the same plant, after being made to vegetate in the light for 30 days, contained $\frac{1}{24}$th of its weight of carbonaceous matter.† Hassenfratz ascertained that plants growing in the dark contain much more water, and much less carbon and hydrogen, than plants growing in the light. Sennebier analyzed both with the same result. Plants growing in the dark yielded less hydrogen gas and oil: their resinous matter was to that of plants growing in the light as 2 to 5·5, and their moisture as 13 to 6; they contained even one-half less of fixed matters.

The quantity of carbonic acid thus absorbed is considerable. In Saussure's experiments, the plants absorbed daily more than their own bulk of this gas: but when they grow in the open air, where the quantity of carbonic acid is much less considerable, not exceeding $\frac{1}{300}$th part, the proportion absorbed is no doubt less.

10. Ingenhousz found that plants emit no oxygen when made to vegetate in the dark, and that in these circumstances they rather injure air than improve it. Now, as the emission of oxygen has

* I presume that Saussure ascertained merely that the new portion of gas, to which he has given the name of azote, did not diminish with oxygen, and did not render lime-water turbid. Many other gases possess these properties. It might have been some inflammable gas. Hydrogen would have detonated; but some of the compound inflammable gases would not, when diluted so largely with common air. Or the increase of azote may have been only apparent, and occasioned by the abstraction of a portion of the carbonic acid gas.

† Mem. Par. 1786.

been found to depend upon the absorption of carbonic acid, it is probable that this acid is absorbed only in the light. Saussure indeed has endeavoured to prove, that plants, even in the dark, absorb and decompose carbonic acid; but the quantity, if any, must be so extremely small that it cannot well be appreciated.

III. The green colour of plants has been shown, by Sennebier, to depend upon the absorption of carbonic acid. It appears only when plants vegetate in the light; for when they vegetate in the dark they are white; and when exposed to the light they acquire a green colour in a very short time, in whatsoever situation they are placed, even though plunged in water, provided always that oxygen be present; for Mr Gough has shown, that light without oxygen has not the power of producing the green colour.*

Sennebier has observed, that when plants are made to vegetate in the dark, their etiolation is much diminished by mixing a little hydrogen gas with the air that surrounds them.† Ingenhousz had already remarked, that when a little hydrogen gas is added to the air in which plants vegetate, even in the light, it renders their verdure deeper:‡ and he seems to think also, that he has proved by experiments, that plants absorb hydrogen gas in these circumstances.§ Mr Humbolt has observed that the *poa annua* and *compressa*, *plantago lanceolata*, *trifolium arvense*, *chieranthus cheiri*, *lichen verticillatus*, and several other plants which grow in the galleries of mines, retain their green colour even in the dark, and that in these cases the air around them contains a quantity of hydrogen gas. This philosopher concludes, from his observations, that the white colour of etiolated plants is occasioned by their retaining an unusual proportion of oxygen, and that this is prevented by surrounding them with hydrogen gas. This may perhaps be true in certain cases; but the experiments of Mr Gough, mentioned above, are sufficient to prove that the retention of oxygen is not the only difference between green and etiolated plants.‖

The green colouring matter of plants has been shown by Rouelle to be of a resinous nature. From this, and from the circumstance of its being formed only in the light, Berthollet has inferred that the leaves of plants have the property of decomposing water as well as carbonic acid when exposed to the light of the sun. The oxygen emitted, according to him, is derived partly from the decomposed carbonic acid and partly from the water, while the carbon and hydrogen enter into the composition of the inflammable parts of the plant. This ingenious theory, though sufficiently probable, is not susceptible of direct proof. From the experiments of Saussure, we learn, that when plants are made to vegetate in pure water, in atmospheres destitute of carbonic acid gas, the quantity of their fixed matter does not increase; but when their atmospheres contain

* Man. Mem. iv. 501. † Encyc. Meth. Physiol. Veget. 75.
‡ Ann. de Chim. iii. 57. § Ibid. 61.
‖ Plants of a white colour, from vegetating in the dark, are called *etiolated*, from a French word which signifies a *star*, as if they grew by *star-light*.

this acid gas, the increase of weight which they receive is considerably greater than can be accounted for by the carbon and oxygen derived from the carbonic acid absorbed.* Hence it is clear, that a portion of the water must enter into their composition. It is more likely that the elements of this portion arrange themselves in a different way, than that they still continue in a state of water. These facts certainly strengthen the hypothesis of Berthollet. Indeed, if we consider the great quantity of hydrogen contained in plants, it is difficult to conceive how they should obtain it, provided the water which they absorb does not contribute to furnish it.†

IV. Plants will not vegetate unless atmospheric air or oxygen gas have access to their leaves. This was rendered probable by those philosophers who, about the end of the seventeenth century, turned their attention particularly towards the physical properties of the air; but Dr Ingenhousz was perhaps the first of the modern chemists who put it beyond doubt. He found that carbonic acid gas, azotic, and hydrogen gas, destroyed plants altogether, unless they were mixed with atmospheric air or oxygen gas. He found also, that plants grew very well in oxygen gas and in atmospheric air.‡ From these experiments, it was pretty clear that the leaves of plants absorb oxygen; and the whole series of chemical experiments on plants led to the supposition that this absorption was confined to the night. The subject has lately been very fully investigated by Saussure, who has not only confirmed these suppositions by decisive experiments, but added many new facts not previously suspected.§

1. The greater number of plants refuse to vegetate when confined in azotic gas. Those only continue to live which are abundantly supplied with green parts, as the *cactus opuntia*, &c. When plants continue to vegetate in azote, it is because they give out a portion of oxygen during the day; the absorption of which during the night preserves them.‖

2. When the leaves of plants are put in contact with common air during the night, they diminish the bulk of their atmosphere by absorbing oxygen. Some plants change, at the same time, a portion of the oxygen into carbonic acid, while others form no perceptible quantity of this last gas. The leaves, for example, of the *cactus opuntia*, *crassula cotyledon*, *sempervivum tectorum*, *agave Americana*, and *stapelia variegata*, simply absorb oxygen; while the leaves of the *quercus robur*, *sedum reflexum*, *æsculus hippocastanum*, and *robinia pseudo-acacia*, absorb oxygen, and form a portion of carbonic acid, inferior in quantity to the oxygen which has disappeared.¶

3. This inspiration of oxygen takes place only when the leaves retain their organized form. If this be destroyed, by reducing

* Recherches, p. 217.

† Mr F. Mariet has shown that mushrooms plunged under water and exposed to the sun give out hydrogen gas. He has rendered it probable that this is owing to the decomposition of water, and the absorption of the oxygen by the mushrooms. See Ann. de Chim. et de Phys. xl. 318.

‡ Ingenhousz, ii. passim. § Recherches, p. 60. ‖ Ibid. p. 197.

¶ Saussure, ibid. p. 61.

them to a paste for example, all absorption of oxygen is prevented, though a portion of it is even then converted into carbonic acid by the action of the carbonaceous matter present.*

4. The oxygen thus inspired by the leaves of plants, is not separated from them again by putting them into the exhausted receiver of the air-pump. By that means, indeed, they yield a little air, but always much less than the oxygen absorbed; and this air is precisely of the same nature with the atmosphere in which they were confined. Neither is the oxygen extricated by exposing the leaves to the greatest heat which they are capable of bearing without being destroyed.†

5. There is reason to believe that the oxygen gas thus absorbed by plants is converted into carbonic acid within the plant, and that it is only after the plant is *saturated* with this acid (if the expression may be permitted), that the surrounding oxygen is partly converted into carbonic acid, by combining with the carbonaceous matter of the plant. When the leaves are exposed to the light, this carbonic acid is decomposed, and a quantity of oxygen thrown out, usually greater than what was inspired. But the oxygen given out in the light (when plants grow in atmospheres destitute of carbonic acid) is always proportional to the oxygen inspired during the night; being always greatest when the plant has absorbed the greatest quantity of oxygen.

6. Plants differ very much from each other in the quantity of oxygen which their leaves absorb during the night. Fleshy-leaved plants absorb the least oxygen; probably because they emit no carbonic acid gas. Hence they can vegetate in high situations where the atmosphere is rarefied. Next in order come the evergreen trees, which though they absorb more oxygen than the fleshy-leaved plants, yet require much less than those trees which lose their leaves during winter. Those plants which flourish in marshy ground likewise absorb but little oxygen. The following tables exhibit the result of Saussure's experiments on this point. The first column contains the names of the plants whose leaves were employed; the second the month in which the experiments were made; and the third the bulk of oxygen absorbed, supposing the bulk of the leaves used in each experiment to be always 1·00.‡

I. *Leaves of Evergreen Trees.*

Leaves of	Time.	Oxygen absorbed.
Illex aquifolium . .	September . .	0·86
Buxus sempervirens .	September . .	1·46
Prunus laurocerasus .	May . . .	3·20
Ditto . . .	September . .	1·36
Viburnum tinus . .	September . .	2·23
Hedera helix . .	September . .	1·00

* Saussure, Recherches, p. 74. † Recherches, p. 69. ‡ Ibid. p. 99.

Leaves of	Time.	Oxygen absorbed.
Vinca minor	June	1·50
Ditto	September	0·93
Pinus abies	September	3·00
Bupleurum frùticosum	May	4·00
Juniperus sabina	June	2·60
Juniperus communis	June	2·40

II. *Leaves of Trees which lose their Leaves in Winter.*

Leaves of	Time.	Oxygen absorbed.
Fagus sylvatica	August	8·00
Carpinus betulus	May	5·00
Ditto	September	6·00
Quercus robur	May	5·50
Ditto	September	5·50
Æsculus hippocastanum	September	4·80
Populus alba	May	6·20
Ditto	September	4·36
Prunus Armeniaca	September	8·00
Amygdalus Persica	June	6·60
Ditto	September	4·20
Juglans regia	May	6·60
Ditto	September	4·40
Platanus occidentalis	September	3·00
Robinia pseudo-acacia	May	5·00
Ditto	September	6·70
Syringa vulgaris	May	3·36
Ditto	September	2·20
Fraxinus excelsior	May	4·32
Ditto	September	3·71
Pyrus	May	5·20
Ditto	September	3·40
Rosa centifolia	June	5·40
Fagus castanea	July	5·60

III. *Leaves of Herbaceous Plants, not Aquatic.*

Leaves of	Time.	Oxygen absorbed.
Solanum tuberosum	September	2·50
Brasica oleracea	Ditto, young leaves	2·40
Ditto	Sept., old leaves	2·00
Urtica urens	September	2·00
Mercurialis annua	Sept., in flower	2·33
Daucus carota	September, ditto	1·90
Vicia faba	Before flowering	3·70
Ditto	In flower	2·00
Ditto	After ditto	1·60

Leaves of	Time.	Oxygen absorbed.
Lilium candidum	May, in flower	0·66
Ditto	Sept., after ditto	0·50
Tropæolum majus	Sept., in flower	3·00
Digitalis ambigua	July	2·00
Brassica rapa	Sept., in flower	1·25
Avena sativa	June, before ditto	2·70
Triticum æstivum	May, before ditto	5·00
Pisum sativum	May, in flower	3·72
Ruta graveolens	August	2·00

IV. *Leaves of Aquatic Plants.*

Leaves of	Time.	Oxygen absorbed.
Alisma plantago	August	0·70
Inula dysenterica	September	1·60
Epilobium molle	Sept., in flower	1·90
Sisymbrium nasturtium	September	1·60
Polygonum Persicaria	Sept., in flower	2·00
Veronica beccabunga	September	1·70
Ranunculus reptans	September	1·50
Lythrum salicaria	May, before flower	2·30
Caltha palustris	May	1·00
Carex acuta	May	2·25

V. *Leaves of the Fleshy Plants.*

Leaves of	Time.	Oxygen absorbed.
Cactus opuntia	August	1·00
Agave Americana	August	0·80
Sempervivum tectorum	July	1·00
Sedum globosum	September	1·50
Saxifraga cotyledon	September	0·60
Sedum reflexum	June	1·70
Stapelia variegata	July	0·63
Mesembryanthemum deltoides	July	1·70

7. It is not improbable, that by the absorption of oxygen, and the formation of carbonic acid, a portion of heat may be evolved, as Saussure supposes; though the quantity must be too small to be appreciated. It appears, that in certain cases a very considerable degree of heat is produced by vegetables; though it has not yet been ascertained whether the appearance of it is connected with the absorption of oxygen.

It has been shown in a preceding Chapter, that in certain cases a good deal of heat is evolved by plants, while the oxygen absorbed and converted into carbonic acid is proportionally great. It is not

unreasonable to suppose, that one object in view in making plants absorb oxygen gas during the dark, was to prevent the temperature of the plants from sinking too low.

8. It appears, from the experiments of Saussure, that the roots absorb oxygen as well as the leaves, and that they transmit the carbonic acid formed to the leaves to be decomposed. The branches likewise absorb it. Flowers do not expand without its presence.

Thus it appears that during the night plants absorb oxygen; that they form with it carbonic acid; that a portion of this gas is sometimes emitted, together with a little azote; but that the greatest part is retained and decomposed by the leaves during the day. Plants will not live without this nightly inspiration, even though supplied with carbonic acid, provided the oxygen formed by them during the day be constantly withdrawn at the approach of night.

V. The leaves of plants absorb water as well as oxygen from the air. This had been suspected in all ages: the great effect which dew, slight showers, and even wetting the leaves of plants, have in recruiting their strength, and making them vegetate with vigour, are so many proofs that the leaves imbibe moisture from the atmosphere. Hales rendered this still more probable, by observing that plants increase considerably in weight when the atmosphere is moist; and Mr Bonnet put the matter beyond a doubt in his *Researches concerning the Use of the Leaves.* He showed that leaves continue to live for weeks when one of their surfaces is applied to water; and that they not only vegetate themselves, but even imbibe enough of water to support the vegetation of a whole branch, and the leaves belonging to it. He discovered also, that the two surfaces of leaves differ very considerably in their power of imbibing moisture; that in trees and shrubs the under surface possesses almost the whole of the property, while the contrary holds in many of the other plants; the kidney-bean for instance.

These facts prove not only that the leaves of plants have the power of absorbing moisture, but also that the absorption is performed by very different organs from those which emit moisture; for these organs lie on different sides of the leaf. If we consider that it is only during the night that the leaves of plants are moistened with dew, we can scarcely avoid concluding, that, except in particular cases, it is during the night that plants imbibe almost all the moisture which they do imbibe.

Thus we have seen that the leaves of plants perform very different operations at different times. During the day they are giving out moisture, absorbing carbonic acid gas, and emitting oxygen gas; during the night on the contrary, they are absorbing moisture, giving out carbonic acid gas, and absorbing oxygen gas.

By these processes, and perhaps also by others which have not yet been detected, the sap of plants is new modelled, and brought to the state which is adapted for the nourishment of the plant. To describe in what manner these changes take place is impossible; because we neither know precisely the substance into which the sap

has been converted by the operations performed during the day, nor the new substances formed by the operations of the night. We have reason, however, to conclude, that during the day the carbon of the sap is increased, and that during the night the hydrogen and oxygen are increased; but the precise new substances formed are unknown to us. Nor let any one suppose that the increase of the hydrogen and of the oxygen of the sap is the same thing as the addition of a quantity of water. In water, oxygen and hydrogen are already combined together in a certain proportion; and this combination must be broken before these elementary bodies can enter into those triple compounds with carbon, of which a great part of the vegetable products consist. We have not the smallest conception of the manner in which these triple combinations are formed, and as little of the manner in which the bodies which compose vegetable substances are combined together. The combination may, for any thing we know to the contrary, be very complicated: though it consists wholly of three ingredients: and analogy leads us to suppose that it actually is very complicated: for in chemistry it may be considered as a truth, to which at present few or no exceptions are known, that bodies are decomposed with a facility inversely as the simplicity of their composition; that is to say, that those bodies which consist of the fewest ingredients are most difficultly decomposed, and that those which are formed of many ingredients are decomposed with the greatest facility.

Neither let any one suppose that the absorption of carbonic acid gas during the day is balanced by the quantity emitted during the night; and that therefore there is no increase of carbon; for Ingenhousz and Saussure have shown that the quantity of oxygen gas emitted during the day is much greater than the carbonic acid gas emitted during the night; and that in favourable circumstances, the quantity of oxygen gas in the air surrounding plants is increased and the carbonic acid gas diminished; so much so, that both Dr Priestley and Dr Ingenhousz found, that air which had been spoiled by a lighted candle, or by animals, was rendered as good as ever by plants. Now we know that combustion and respiration diminish the oxygen gas, and add carbonic acid gas to air; therefore vegetation, which restores the purity of air altered by these processes, must increase the oxygen, and diminish the carbonic acid gas of that air; consequently the quantity of carbonic acid gas absorbed by plants during the day is greater than the quantity emitted by them during the night; and of course the carbon of the sap is increased in the leaves.

It is true, that when plants are made to vegetate for a number of days in a given quantity of air, its ingredients are not found to be altered. Thus Hassenfratz ascertained that the air, in which young chesnuts vegetate for a number of days together, was not altered in its properties, whether the chesnuts were vegetating in water or in earth;* and Saussure, junior, proved that peas growing for ten

* Ann. de Chim. xiii. 325.

days in water did not alter the surrounding air.* But this is precisely what ought to be the case, and what must take place, provided the conclusions which I have drawn be just. For if plants only emit oxygen gas by absorbing and decomposing carbonic acid gas, it is evident, that unless carbonic acid gas be present, they can emit no oxygen gas; and whenever they have decomposed all the carbonic acid gas contained in a given quantity of air, we have no longer any reason to look for their emitting any more oxygen gas; and if the quantity of carbonic acid gas emitted during the night be smaller than that absorbed during the day, it is evident that during the day the plant will constantly decompose all the acid which had been formed during the night. By these processes the mutual changes of day and night compensate each other; and they are prevented from more than compensating each other by the forced state of the plant. It is probable, that when only part of a plant is made to vegetate in this forced state, some *carburetted sap* (if I may be allowed the expression) is supplied by the rest of the plant; and that therefore the quantity of carbonic acid gas emitted during the night may bear a nearer proportion to that emitted in a state of nature than that of the absorption of fixed air can possibly do. And probably, even when the whole plant is thus confined, the nightly process goes on for a certain time at the expense of the carbon already in the sap; for Hassenfratz found, that in these cases the quantity of carbon in the plant after it had vegetated for some time in the dark, was less than it had been when it began to vegetate.† This is the reason that plants growing in the dark, when confined, absorb all the oxygen gas, and emit carbonic acid gas: and whenever this has happened, they die; because then neither the daily nor nightly processes can go on.

CHAPTER VII.

OF THE PECULIAR JUICES OF PLANTS.

By these changes which go on in the leaves, the nature of the sap is altogether changed. It is now converted into what is called the *peculiar juice*, or *true sap*, and is fit for being assimilated to the different parts of the plant, and for being employed in the formation of those secretions which are necessary for the purposes of the vegetable economy.

The leaves, therefore, may be considered as the digesting organs of plants, and as equivalent in some measure to the stomach and

* Ann. de Chim. xxiv. 139. † Ibid. xiii. 188.

lungs of animals. The leaves consequently are not mere ornaments; they are the most important parts of the plant. Accordingly we find, that whenever we strip a plant of its leaves, we strip it entirely of its vegetating powers till new leaves are formed. It is well known that when the leaves of plants are destroyed by insects they vegetate no longer, and that their fruit never makes any farther progress in ripening, but decays and dries up. Even in germination no progress is made in the growth of the stem till the seed-leaves appear. As much food indeed is laid up in the cotyledons as advances the plant to a certain state: the root is prepared, and made ready to perform its functions; but the sap which it imbibes must be first carried to the seed-leaves, and digested there, before it be proper for forming the plumula into a stem. Accordingly if the seed-leaves are cut off, the plant refuses to vegetate.

It will be very natural to ask, if this be true, how come the leaves themselves to be produced? I had endeavoured to render it probable, that food for the purpose of nourishing and developing them was laid up in the buds themselves; but the experiments of Mr Knight, formerly detailed, have shown that the alburnum is the part of the tree in which this food is deposited. After the plant has developed all the parts which are to appear during the summer, and after the buds are fabricated and rolled up, the leaves still continue to manufacture new food, and to send it to the alburnum. Here it is deposited, and employed next spring in feeding and developing those organs of plants which are absolutely necessary for enabling them to perform the functions of vegetation. From this important fact, Mr Knight has drawn a number of curious consequences, of great importance to the practical gardener and farmer.

This deposition of food for the future supply of the plant explains to us why the branch of a vine, if it be introduced into a hot-house during the winter, puts forth leaves and vegetates with vigour, while every other part of the plant gives no signs of life. It explains to us also why the sap flows out of trees very readily in spring before the leaves appear, but after that the bleeding ceases altogether. It is evident that there can be scarcely any circulation of sap before the leaves appear; for as there is no outlet, when the vessels are once full they can admit no more. It appears, however, from the bleeding, that the roots are capable of imbibing, and the vessels of circulating, the sap with vigour. Accordingly, whenever there is an outlet, they perform their functions as usual, and the tree bleeds; that is, they send up a quantity of sap to be digested as usual: but as there are no digesting organs, it flows out, because the sap that flows out would not have been imbibed at all, had it not been for the artificial opening. But when the digestive organs appear, the tree will not bleed; because these organs require all the sap, and it is constantly flowing to them.

If a tree be deprived of its leaves, new leaves make their appearance, because they are already prepared for that purpose. But

what would be the consequence if a tree were deprived of its leaves and of all its buds for five years back? That plants do not vegetate without leaves is evident from an experiment of Duhamel. He stripped the bark off a tree in ringlets, so as to leave five or six rings of it at some distance from each other, with no bark in the intervals. Some of these rings had buds and leaves; these increased considerably in size; but one ring which had none of these remained for years unaltered. Mr Knight found that a shoot of the vine, when deprived of its leaves died altogether.*

The *succus proprius*, or *peculiar juice* of plants, may be considered as analogous to the blood of animals. It is the food altered by digestion, and rendered fit for being assimilated and converted into a part of the plant itself by the subsequent processes of vegetation. That it flows from the leaves of the plant towards the roots appears from this circumstance, that when we make an incision into the plant, into whatever position we put it, much more of the *succus proprius* flows from that side of the wound which is next the leaves and branches than from the other side: and this happens even though the leaves and branches be held undermost.† When a ligature is tied about a plant, a swelling appears above but not below the ligature.

The vessels containing the peculiar juice have been traced by Mr Knight from the leaves into the cortical layers of the inner bark.‡ Hedwig, who has examined the vessels of plants with very great care, seems to consider them as of the same structure with the tracheæ; but Mr Knight is of a different opinion. It appears evidently from the experiments of this last gentleman, that they communicate with no part of the plant which is situated at a greater distance from the root than the leaf from which they themselves originate. For when two circular incisions are made through the bark of a branch above and below a leaf, and at some distance from it, only that part of the portion confined between the two incisions which is situated below the leaf increases in size. From the experiments of Mr Knight, there is reason to believe that these vessels are much better calculated to carry the true sap from the leaves towards the roots, than in the contrary direction. By passing the slender shoots of a vine through the earth of a garden-pot, he made them send out roots. The shoots were then cut off from the parent tree, leaving an equal portion on each side of this new root. Each of these portions was turned up at a similar angle, and had a bud at a little distance from the cut-off extremity. Here were two stems growing from one root. But the one was obviously inverted, while the other was in its natural position. In the first, the wood between the bud and the cut-off extremity increased in size; but in the other it did not: indicating a disposition in the true sap to move in its original direction from the leaves to the root. In like manner,

* Phil. Trans. 1801, p. 338. † Bell, Manch. Mem. ii. 402.
‡ Phil. Trans. 1801, p. 337.

when shoots of gooseberry and currant bushes were planted inverted, the upper part always decayed.* These experiments are favourable to the opinion, that these vessels are furnished with valves.

When all communication between the leaves and roots is cut off, by removing a portion of the bark all round the tree, it appears, from the experiments of Knight, that the alburnous vessels acquire the property of transmitting a portion of the true sap to the roots, so as to maintain the powers of vegetating; but the quantity is greatly diminished. The surplus appears to be lodged in the alburnum, which thus becomes denser; and if the plant be allowed to vegetate, this food is expended next season upon the upper part of the plant. Thus the quantity of blossom on the branch of an apple tree is greatly increased, by removing a section of its bark the season before the blossom is to appear.†

The true sap is easily known by its colour and its consistence. In some plants it is green, in some red, in many milky. It cannot be doubted that its motion in the vessels is performed in the same way as that of the sap.

If we had any method of obtaining this peculiar juice in a state of purity, the analysis of it would throw a great deal of light upon vegetation; but this is scarcely possible, as we cannot extract it without dividing at the same time the vessels which contain the sap. In many cases, however, the peculiar juice may be known by its colour, and then its analysis may be performed with an approach towards accuracy. The facts respecting its constituents, hitherto ascertained by chemists, have, as far as I am acquainted with them, been detailed in the preceding Chapter. These experiments prove, as might have been expected, that the peculiar juices differ very considerably from each other, and that every plant has a juice peculiar to itself. Hence it follows, that the processes which go on in the leaves of plants must differ at least in degree, and that we have no right to transfer the conclusions deduced from experiments on one species of plants to those of another species. It is even probable, that the processes in different plants are not the same in kind; for it is not reasonable to suppose, that the phenomena of vegetation in an agaric or a boletus are precisely the same as those which take place in trees and in larger vegetables, on which alone experiments have hitherto been made.

The true sap is conveyed to every part of the plant; and all the substances which we find in plants, and even the organs themselves by which they perform their functions, are formed from it. But the thickest veil covers the whole of these processes; and so far have philosophers hitherto been from removing this veil, that they have not even been able to approach it. All these operations, indeed, are evidently chemical decompositions and combinations; but

* Nicholson's Jour. x. 289.

† Knight on the Inverted Action of the Alburnous Vessels of Trees. Phil. Trans. 1806.

we neither know what these decompositions and combinations are, nor the instruments in which they take place, nor the agents by which they are regulated.

CHAPTER VIII.

OF THE DECAY OF PLANTS.

Such, as far as I am acquainted with them, are the changes produced by vegetation. But plants do not continue to vegetate for ever; sooner or later they decay and wither, and rot, and are totally decomposed. This change indeed does not happen to all plants at the end of the same time. Some live only for a single season, or even for a shorter period; others live two seasons, others three, others a hundred or more; and there are some plants which continue to vegetate for a thousand years; but sooner or later they all cease to live: and then those very chemical and mechanical powers which had promoted vegetation combine to destroy the remains of the plant. Now, What is the cause of this change? Why do plants die?

This question can only be answered by examining with some care what it is which constitutes the *life* of plants: for it is evident, that if we can discover what that is which constitutes the life of a plant, it cannot be difficult to discover whatever constitutes its death.

Now, the phenomena of vegetable life are in general *vegetation*. As long as a plant continues to vegetate, we say that it lives; when it ceases to vegetate, we conclude that it is dead.

The life of vegetables, however, is not so intimately connected with the phenomena of vegetation that they cannot be separated. Many seeds may be kept for years without giving any symptom of vegetation; yet if they vegetate when put into the earth, we say that they possess life; and if we would speak accurately, we must say also that they possessed life even before they were put into the earth: for it would be absurd to suppose that the seed *obtained* life merely by being put into the earth. In like manner many plants decay, and give no symptoms of vegetation during winter; yet if they vegetate when the mild temperature of spring affects them, we consider them as having lived all winter. The life of plants, then, and the phenomena of vegetation, are not precisely the same thing; for the one may be separated from the other, and we can even suppose the one to exist without the other. Nay, what is more, we can, in many cases, *decide*, without hesitation, that a vegetable is not dead, even when no vegetation appears; and the proof which we have for its life is, that it *remains unaltered;* for we know, that when

a vegetable is dead, it soon changes its appearance, and falls into decay.

Thus it appears that the *life* of a vegetable consists in two things: 1. In remaining unaltered, when circumstances are unfavourable to vegetation; 2. In exhibiting the phenomena of vegetation, when circumstances are favourable. When neither of these two things happens, we may say that a vegetable is dead.

The phenomena of vegetation have been enumerated above. They consist in the formation or expansion of the organs of the plant, in the taking in of nourishment, in carrying it to the leaves, in digesting it, in distributing it through the plant, in augmenting the bulk of the plant, in repairing decayed parts, in forming new organs when they are necessary, in producing seeds capable of being converted into plants similar to the parent. The *cause* of these phenomena, whatever it may be, is the *cause* also of *vegetable life*, and may be distinguished by the name of the *vegetative principle*. But an inquiry into the nature of this principle belongs to the science of *physiology*, and would be foreign to the nature of this work.

The death of plants, if we can judge from the phenomena, is owing to the organs becoming at last altogether unfit for performing their functions, and incapable of being repaired by any of the powers which the vegetative principle possesses.

From the experiments of M. F. Marcet, it appears that metallic poisons act upon vegetables nearly as on animals. They are absorbed, conveyed to the different parts of the plants, and alter or destroy the tissue.

The vegetable poisons which, in animals, act on the nervous system, as opium, nux vomica, menispermum cocculus, prussic acid, belladonna, alcohol, and oxalic acid, also cause the death of plants. Does not this favour the opinion of those who believe, that there is something in plants analogous to the nerves of animals?*

* Mem. de la Societé Naturelle de Geneve, iii. 37.

DIVISION IV.

OF THE DECOMPOSITION OF VEGETABLE SUBSTANCES.

The most striking distinction between the substances belonging to the mineral kingdom, and those which make a part of animals or vegetables, is the following: mineral bodies show little or no tendency to change their nature; and, when left to themselves, undergo no spontaneous decompositions: whereas animal and vegetable substances are continually altering; and when left to themselves in favourable circumstances, always run through a regular set of decompositions.

We have seen above, that during vegetation the constituents of plants are continually going through a regular set of changes, losing the properties of one substance, and assuming those of another. Thus a substance, which in the young plant has the properties of mucilage, assumes in the old the properties of starch; what in green fruit is an acid, in ripe fruit becomes sugar. Vegetable principles, then, are not fixed or stationary in the living plant; they are gradually running into one another. But this tendency to change, or rather this continual decomposition in consequence of the mutual reaction of the different simple substances of which the vegetable principles are composed, is by no means confined to the living state. It goes on with equal or with greater energy in favourable circumstances in vegetable matter after it has been completely separated from the living plants. It has been observed that this tendency to spontaneous decomposition is usually greater in animal than in vegetable bodies; and that those vegetable bodies, in which the tendency is greatest, bear the closest resemblance to animal matter: hence the common chemical phrase, that such substances are *more animalized*. This is the case with *gluten* in particular, which undergoes spontaneous decomposition more rapidly than most other vegetable bodies.

During the spontaneous decomposition which vegetable substances undergo, it is obvious that the simple substances of which they are composed must unite together in a different manner from that in which they were formerly united, and form a new set of compounds which did not formerly exist. Now it has been observed that the specific gravity of these new compounds is almost always less than that of the old body. Some of them usually fly off in the state of gas or vapour. Hence the odour that vegetable bodies emit during the whole time that they are running through the series of their changes. When the odour is very offensive or noxious, the spon-

taneous decomposition is called *putrefaction;* but when the odour is not offensive, or when any of the new compounds formed is applied to useful purposes, the spontaneous decomposition is called *fermentation.* This word was first introduced into chemistry by Van Helmont.* It is supposed by some to have originated from the intestine motion which is always perceptible while vegetable substances are fermenting; while by others it is derived from the heat which in these cases is always generated. The term *fermentation* is now very often applied to all the spontaneous changes which vegetable bodies undergo without regard to the products. It therefore, in that sense, includes *putrefaction;* and certainly there is no impropriety in thus extending the term so as to make it comprehend every case of spontaneous decomposition. By fermentation, then, is now meant all the spontaneous changes which take place in vegetable substances after they are separated from the living plant.

All the phenomena of fermentation lay for many years concealed in the completest darkness, and no chemist was bold enough to hazard even an attempt to explain them. They were employed, however, and without hesitation too, in the explanation of other phenomena; as if giving to one process the name of another, of which we are equally ignorant, could, in reality, add any thing to our knowledge. The darkness which enveloped these phenomena has begun to disperse; but they are still surrounded with a very thick mist; and we must be much better acquainted with the composition of vegetable substances, and the mutual affinities of their ingredients, than we are at present, before we can explain them in a satisfactory manner.

Fermentation never takes place unless vegetable substances contain a certain portion of water, and unless they are exposed to a temperature at least above the freezing point. When dry, or freezing, many of them continue long without alteration. Hence we have an obvious method of preventing fermentation.

If we take a view of all the vegetable principles described in the first part of this treatise, we shall find that they differ much from one another in their tendency to run into fermentation. Gum, sarcocol, starch, indigo, wax, resins, camphor, caoutchouc, gum resins, wood, and suber, though mixed with water, and placed in the most favourable temperature, show scarcely any tendency to change their nature. Oils absorb oxygen from the atmosphere, but too slowly to produce any intestine motion. Tannin, some of the acids, and extractive, are gradually decomposed; the surface of the liquid becomes mouldy, and an insipid sediment falls to the bottom; and when the process has once begun, it goes on with greater rapidity. Albumen and fibrin putrefy very quickly, but the products have not been ascertained; gluten gradually changes into a kind of cheese.

But it is when several of the vegetable principles are mixed together, that the fermentation is most perceptible, and the change most

* Stahl's Fundament. Chem. i. 124.

remarkable. Thus when gluten is added to a solution of sugar in water, the liquid soon runs into vinegar, or in certain cases to alcohol and vinegar. When gluten is mixed with starch and water, alcohol and vinegar usually make their appearance; but the greatest part of the starch remains unaltered. It has been observed that certain substances are peculiarly efficacious in exciting fermentation in others. These substances have received the name of *ferments*.

But the phenomena of fermentation do not appear in their greatest perfection in our artificial mixture of vegetable principles. Those complicated parts of plants in which various principles are already mixed by Nature, especially the liquid parts, exhibit the finest specimens of it; such as the sap of trees, the juices of fruits, the decoction of leaves, seeds, &c. It is from such natural mixtures that we obtain all the products of fermentation which mankind have applied to useful purposes; such as indigo, beer, bread, vinegar, wine, &c. In the present imperfect state of the subject, I shall satisfy myself with an account of the most important of these products of fermentation, and of the phenomena which take place during their formation.

CHAPTER I.

OF THE VINOUS FERMENTATION.

Under this name is comprehended every species of fermentation which terminates in the formation of an intoxicating liquid. Now these liquids, though numerous, may be comprehended under two general heads; namely, those which are obtained from the *decoction of seeds*, and those which are obtained from the *juices of plants*. The liquids of the first class are denominated *beer* or *wash*, those of the second *wine*.

SECTION I.—OF BEER.

The earliest writer who mentions *beer*, is Herodotus, who was born in the first year of the 74th Olympiad, or 444 years before the commencement of the Christian era. He informs us that *beer* was the common drink of the Egyptians, and that it was manufactured from barley, because vines did not grow in their country.* In the time of Tacitus, whose treatise on the *Manners of the Germans* was written about the end of the first century of the Christian era, beer was the common drink of the Germans.† Pliny mentions beer

* Euterpe, c. 77, Οἶνῳ δ' ἐκ κριθίων πεποιημένῳ διαχρέονται· οὐ γαρ σφι εἰσι ἐν τῃ χωρῃ ἀμπελοι.

† Potui humor ex hordeo aut frumento in quandam similitudinem vini corruptus. *De Moribus Germanorum*, c. 23.

as employed in Spain, under the names of *cælia* and *ceria*, and in Gaul under the name of *cervisia*.*

Almost every species of corn has been used for the manufacture of beer. In Europe it is usually made from *barley*, in India from *rice;* in the interior of Africa, from the seeds of the *holcus spicatus*.† But whatever grain is employed, the process is nearly the same. But as grain in its natural state does not answer so well for making beer, it is usual in the first place to convert it into malt.

I. Malting. The term *malt* is applied to grain which has been made to germinate artificially to a certain extent, after which the process is stopped by the application of heat.

The barley is steeped in cold water for a period which (as regulated by law) must not be less than 40 hours; but beyond that period the steeping may be continued as long as is thought proper. Here it imbibes moisture, and increases in bulk; while at the same time a quantity of carbonic acid is emitted, and a part of the substance of the husk is dissolved by the steep-water. The proportion of water imbibed depends partly on the barley, and partly on the length of time that it is steeped. From the average of a good many trials, it appears that the medium increase of weight from steeping, may be reckoned 0·47; that is to say, every 100 pounds of barley when taken out of the steep weigh 147 pounds. The average increase of bulk is about a fifth; that is to say, that 100 bushels of grain, after being steeped, swell to the bulk of 120 bushels. The carbonic acid emitted while the barley is in the steep is inconsiderable; and it is probable from the experiments of Saussure, that it owes its formation, at least in part, to the oxygen held in solution by the steep-water.

The steep-water gradually acquires a yellow colour, and the peculiar smell and taste of water in which straw has been steeped. The quantity of matter which it holds in solution varies from $\frac{1}{30}$th to $\frac{1}{100}$th of the weight of barley. It consists chiefly of an extractive matter of a yellow colour and disagreeable bitter taste, which deliquesces in a moist atmosphere, and contains always a portion of nitrate of soda. It holds in solution most of the carbonic acid disengaged. This extractive matter is obviously derived from the husk of the barley, and is that substance to which that husk owes its colour. Accordingly grain becomes much paler by steeping.

After the grain has remained a sufficient time in the steep, the water is drained off, and the barley thrown out of the cistern upon the malt-floor, where it is formed into a rectangular heap, called the *couch*, about 16 inches deep. In this situation it is allowed to remain about 26 hours. It is then turned, by means of wooden shovels, and diminished a little in depth. This turning is repeated twice a-day or oftener, and the grain is spread thinner and thinner, till at last its depth does not exceed a few inches.

When placed on the couch it begins gradually to absorb oxygen

* Plinii Nat. Hist. lib. xxii. c. 25. † Park's Travels, p. 63, 8vo Edition.

from the atmosphere, and to convert it into carbonic acid; at first very slowly, but afterwards more rapidly. The temperature, at first the same with that of the external air, begins slowly to increase; and in about 96 hours the grain is, at an average, about 10° hotter than the surrounding atmosphere. At this time the grain, which had become dry on the surface, becomes again so moist that it will wet the hand, and exhales at the same time an agreeable odour, not unlike that of apples. The appearance of this moisture is called *sweating*. A small portion of alcohol appears to be volatilized at this period. The great object of the maltman is to keep the temperature from becoming excessive. This they do by frequent turning. The temperature which they wish to preserve varies from 55° to 62°, according to the different modes of malting pursued.

At the period of the sweating the roots of the grains begin to appear, at first like a small white prominence, at the bottom of each seed, which soon divides itself into three rootlets, and increases in length with very great rapidity, unless checked by turning the malt. About a day after the sprouting of the roots, the rudiments of the future stem, called *acrospire* by the maltsters, may be seen to lengthen. It rises from the same extremity of the seed with the root, and advancing within the husk, at last issues from the opposite end: but the process of malting is stopped before it has made such progress.

As the acrospire shoots along the grain, the appearance of the kernel, or mealy part of the corn, undergoes a considerable change. The glutinous and mucilaginous matter is taken up and removed, the colour becomes white, and the texture so loose that it crumbles to powder between the fingers. The object of malting is to produce this change: when it is accomplished, which takes place when the acrospire has come nearly to the end of the seed, the process is stopped by drying the malt upon the kiln. The temperature at first does not exceed 90°; but it is raised very slowly up to 140°, or higher, according to circumstances. The malt is then cleaned, to separate the rootlets, which are considered as injurious.

Such is a short sketch of the process of malting. Barley, by being converted into malt, generally increases two or three per cent. in bulk; and loses, at an average, about a fifth of its weight, or 20 per cent. But of these 20 parts 12 are to be ascribed to kiln-drying, and consist of water, which the barley would have lost had it been exposed to the same temperature: so that the real loss does not exceed eight per cent. From a good many trials, made with as much attention to all the circumstances as possible, the following seems to be the way of accounting for this loss:—

Carried off by the steep-water . .	1·5
Dissipated in the floor . . .	3·0
Roots, separated by cleaning . .	3·0
Waste	0·5
	8·0

The loss on the floor ought to be entirely owing to the separation of carbon by the oxygen of the atmosphere; but were this the only cause, it would be much smaller than three per cent. Two other causes concur to produce this loss:—1. Many of the roots are broken off during the turning of the malt; these wither and are lost, while others grow in their place:—2. A certain portion of the seeds lose the power of germinating, by bruises or other accidents, and these lose a much greater portion than three per cent. of their real weight. From a good many trials, made with as much care as possible, I am disposed to conclude that the quantity of carbon, separated during the whole process of malting, by the formation of carbonic acid gas, does not exceed two per cent. and that the weight of the roots formed amounts often to four per cent. These two, in reality, include the whole real loss of weight which barley sustains when malted. What is lost in the steep, being husk, need scarcely be reckoned.

The roots appear, from the process, to be formed chiefly from the mucilaginous and glutinous parts of the kernel. The starch is not employed in their formation; but undergoes a change, intended no doubt to fit it for the future nourishment of the plumula. It acquires a sweetish taste, and the property of forming a transparent solution with hot water. In short, it approaches somewhat to the nature of sugar, and is probably the same with the sugar into which starch is converted, by boiling it with diluted sulphuric acid.

Malt thus prepared is ground in a mill, and infused in a large cylindrical vessel called the *mash tun*, with somewhat more than its own bulk of water, of a temperature varying from 160° to 180°, according to the fancy of the brewer. The infusion is left covered for two or three hours, and then the liquid drawn off by a cock at the bottom of the vessel. More hot water is afterwards added, and the infusions repeated in a similar manner till the malt is sufficiently exhausted. The liquid thus obtained, is called *wort*.

II. Wort. *Wort* has a brownish-yellow colour, a luscious sweet taste, a peculiar smell, and when the process is properly conducted is perfectly transparent. It consists of the water employed holding the mealy part of the malt in solution. When examined by reagents, it appears to consist chiefly of four different substances held in solution together: namely, 1. A sweet-tasted substance, to which the name of *saccharine matter* has been given. It is by far the greatest in point of quality. This substance when separated has a light-brown colour; when dried at 160°, it forms a brittle mass with a glazed surface; at the temperature of 180°, or a little higher, its colour becomes darker; and if we keep it in that temperature, moistening it occasionally, it becomes at last almost black, loses its sweet taste altogether, and acquires a sharp disagreeable one. In a temperature somewhat higher, but under the boiling point, it is charred. It is very soluble in water, and if once dissolved can scarcely be recovered again by evaporation without considerable loss. Alcohol dissolves it very imperfectly cold, and when heat is

applied it deprives the alcohol of a portion of water, and forms a tough mass like turpentine, which refuses to dissolve. The specific gravity of this saccharine matter is 1·552. It appears to be the essential constituent of wort. 2. Starch. The presence of this substance is easily detected by dropping the infusion of nutgalls into wort; a precipitate appears, which is mostly redissolved by heating the liquid to 120°. 3. The insoluble part of the precipitate is a combination of albumen and tannin. The proportion of gluten in wort is very inconsiderable. That of the starch probably diminishes in proportion as the barley is more completely malted. I have detected starch in pretty old and perfectly transparent ale; but the gluten had disappeared. New ale, however, often contains traces of it. 4. The fourth ingredient in wort is *mucilage*, which precipitates in flakes when the wort is dropped into alcohol. Its quantity is more considerable in the worts last drawn off than in the first worts.

The wort is boiled with a quantity of hops, which vary considerably, but which may be stated in general at about $\frac{1}{10}$th of the weight of the malt.

III. Hops. Hops are the cones of the female flowers of the *Humulus lupulus*, a diœcious plant belonging to the family of *urticeæ*. An account of the chemical nature of hops, so far as it has been investigated, has been given in a preceding Chapter of this volume.

The use of the hops is partly to communicate a peculiar flavour, from the oil which they contain; partly to cover the sweetness of saccharine matter by the bitter principle which they contain; and partly to counteract the tendency which wort has to run into acidity.

IV. Fermentation. When the wort is sufficiently concentrated, it is thrown into very wide flat vessels called *coolers*, placed in the most open situation that can be had. Here it is cooled down to the temperature of about 52°, and then let down into a deep round wooden vessel called the *fermenting tun*. The specific gravity of the wort when put into the fermenting tun varies very much. The wort of strong ale is sometimes as low as 1·060; sometimes as high as 1·127. In the first case it contains 14·25 per cent. of solid matter; in the second 28·2 per cent. The wort of small beer varies from 1·015 to 1·040; the first containing not quite 3·5 per cent. and the second about 9·5 per cent. of solid matter.

If the wort be let down into the fermenting tun at the temperature of 60°, or rather higher, the substances which it holds in solution begin gradually to act upon each other, and to decompose each other. The temperature rises, an intestine motion takes place, a scum collects on the surface, and carbonic acid gas is emitted. This intestine motion is called *fermentation*. The disposition of wort to ferment is not sufficiently great to induce it to do so with the requisite rapidity. It takes place so slowly and imperfectly, that the liquor runs into acidity before the formation of ale has made sufficient progress. To prevent this, it is requisite

to add to the wort some substance which has the property of inducing speedy fermentation. The substance made choice of is *yeast*, or the frothy matter which collects on the surface of the beer while fermenting. The quantity of yeast used by brewers is but small, generally about a gallon to every three barrels of the wort.

The yeast thus added acts upon the saccharine matter held in solution in the wort and decomposes it while it undergoes partial decomposition itself. By this mutual action the saccharine matter disappears, the specific gravity of the wort diminishes, and its properties alter, being converted into the intoxicating liquor called *ale*. During this mutual action the temperature of the liquid increases, and the increase depends upon the violence of the fermentation. In ale worts the rise of temperature is but small, amounting at an average to about 15°, because the quantity of yeast is small; but in the fermentation of wash, it often amounts to 50°, or even more in some cases.

Considerable exertions have been made by chemists to ascertain the nature of the substance in yeast which produces this striking effect upon wort, and to discover it if possible in other substances. Westrumb examined the yeast of beer. From 15360 parts of it he obtained the following substances:—

Potash	13
Carbonic acid	15
Acetic acid	10
Malic acid	45
Lime	69
Alcohol	240
Extractive	120
Mucilage	240
Saccharine matter	315
Gluten	480
Water	13595
	15142

Besides some traces of phosphoric acid and of silica.* But it is obvious, that all these ingredients are not essential. From the experiments of Westrumb, it appears that when the yeast is filtered, a matter remains upon the filter which possesses the properties of gluten; that when this substance is separated the yeast loses the property of exciting fermentation, but recovers it again when the gluten is added. Hence it follows that this glutinous matter is the essential constituent of the yeast. When yeast is kept for some time in cylindrical glass vessels, a white substance not unlike curd separates and swims upon the surface. If this substance be removed the yeast loses the property of exciting fermentation. This substance possesses many of the properties of gluten, though it differs from it in others. Its colour is much whiter, it has not the same

* Crell's Annals, 1796, i. 13.

elasticity; and its particles do not adhere with the same force. It dissolves more readily in acids. I have little doubt that this is the part of yeast which is the real ferment. It may be considered as gluten somewhat altered, and much more disposed to decomposition. It existed, no doubt, in the raw grain, but underwent considerable modifications during the process of malting, and probably others during the fermentation of the beer from which it separated.

That a substance analogous to gluten is the real ferment, appears also from the experiments of Fabroni, who published a treatise on wine-making in 1785, which gained the prize proposed by the Florence Academy. By heating the juice of grapes, and passing it through a filter, he separated an adhesive matter which possessed the properties of gluten. The juice deprived of this substance refused to ferment, but it fermented as usual when the glutinous matter was again added. The observations of Thenard confirm those of Fabroni. He found in the juices of all fruits examined, a substance similar to that described by Fabroni, and which, according to him is absolutely the same with pure yeast. This substance is insipid, does not change vegetable blues, is insoluble in water, loses $\frac{3}{4}$ths of its weight when dried, and is decomposed like animal substances. When 8 parts of it were distilled, they left 2·83 of charcoal, and yielded 1·61 of water, 1·81 of oil, and a quantity of ammonia, which, when saturated with muriatic acid, formed 1·46 of sal ammoniac; the gas obtained weighed 0·38, and consisted of $\frac{1}{5}$th carbonic acid and $\frac{4}{5}$ths of carburetted hydrogen, requiring $1\frac{1}{2}$ time its bulk of oxygen to consume it. Nitric acid, even when diluted, converts it into a species of tallow. With potash it forms a soap, while ammonia is disengaged. When mixed with sugar and a sufficient quantity of water, fermentation takes place, carbonic acid is disengaged, and a vinous liquor formed. By this action the ferment loses the whole of its azote, and becomes incapable of exciting fermentation when mixed with a new portion of sugar.* An experiment of Kirchoff throws considerable light on the nature of yeast. Barley-meal contains both gluten and starch. If pure starch be infused in hot water it is not converted into sugar. Neither does gluten become saccharine matter when treated in the same way. But if a mixture of pure, dried, pulverized wheat gluten and potatoe starch be infused in hot water, the starch is converted into sugar. During the process an acid is evolved. The gluten is little altered in appearance, and if the liquid be filtered most of it remains upon the filter. But it cannot be employed successively a second time to convert starch into sugar. It appears then that it is some substance connected with the gluten that acts upon the starch, and converts it into sugar.†

The essential part of yeast, then, may be considered as altered gluten. When mixed with the wort, this substance acts upon the saccharine matter; the temperature rises, carbonic acid is disengaged, and the saccharine matter is converted into alcohol. The

* Thenard, Ann. de Chim. xlvi. 308. † Schweigger's Jour. xiv. 389.

yeast soon collects on the top of the liquid, but the brewer occasionally mixes it again to continue the fermentation. The quantity of yeast employed being small, the saccharine matter is but imperfectly decomposed. Hence a considerable portion of it still remains in the ale, and gives it that glutinousness and body for which it is remarkable. The specific gravity of the ale varies very much according to the original strength of the wort, and the extent to which the fermentation has been carried. The limits may be stated at about 1·035 and 1·012.

The properties of ale are so well known, that no description is deemed necessary. It possesses intoxicating qualities, and holds a quantity of alcohol in solution; which varies considerably according to the original strength of the wort. I distilled a quantity of London-brewed ale. The specific gravity of the wort was 1·0676. The specific gravity of the ale was 1·0255. One hundred parts of it by weight yielded

9·354 parts of proof spirit of specific gravity . 0·91985

Or,

5·817 parts of alcohol of the specific gravity . 0·825

Another specimen of ale was distilled. The specific gravity of the wort was 1·0813. The specific gravity of the ale after fermentation was 1·02295. One hundred parts of it by weight yielded

11·13 parts of proof spirit

6·92 parts of alcohol of the specific gravity 0·825.

Mr Brande* distilled ale and brown-stout porter. The quantity of alcohol which he extracted from each by measure was as follows:—

Brown stout . .	6·80 per cent.
Ale	8·88

When reduced to weight, the quantity of alcohol of the specific gravity 0·825 obtained from each, will be as follows:—

Brown stout . .	5·61 per cent.
Ale	7·33

V. Wash. Ale being intended as an article of food, and its value depending in a great measure on its flavour and appearance, particular attention is paid to obtain these in as great perfection as possible. But there is another species of ale which is brewed by the distillers, for the express purpose of procuring from it ardent spirits by a subsequent process. The method which they follow is in several respects different. In particular, they endeavour to carry the fermentation to as great a length as possible, because the quantity of spirits is proportional to the saccharine matter decomposed, whatever remains unaltered yielding none. It is here, therefore, that the effects of fermentation can be best observed.

1. In this country the distillers do not brew from pure malt; they use also raw grain. The proportion of malt varies from a third to a tenth part of the raw grain employed. This mixture

* Phil. Trans. 1811, p. 346.

they grind to meal, infuse with water at a heat considerably lower than that of the water used by the brewers, and employ much more agitation to mix it completely. The wort is drawn off and cooled in the usual way, and fresh water poured on to exhaust the grain.

The wort thus formed is not so transparent as that from malt, but its taste is nearly as sweet. It would appear, therefore, that the starch in the raw grain undergoes a certain change during the mashing, and is brought towards the state of saccharine matter.

In this country, where the duty is levied chiefly upon the *wash*,* the distillers make the specific gravity of their wort as high as from 1·084 to 1·110: this they do, not by boiling, but by *lobbing*, that is, by preparing a strong infusion of the flour of malt, or of barley, and malt, and hot water, and adding this almost saturated solution to the wort, till it has acquired the requisite strength. But in Holland, where the duties are levied in a different way, the specific gravity of the wort is much lower.

Some years ago, the very improper regulations to which the distillers in this country were subjected, were very much altered for the better. The distillers were allowed to use wash of any specific gravity which they thought would answer best. They were not obliged, as heretofore, to produce a given quantity of spirits out of every hundred gallons of wash: the duty on malt was so much diminished, that it became the interest of the distillers to employ malt instead of raw grain. The consequence of these changes is, that malt is now commonly used for making spirits in Scotland: the wash is so much weaker than formerly, that the fermentation is more complete, and a greater quantity of spirits is obtained from the same quantity of grain than formerly, and the flavour of the spirits is very much improved.

The wort thus made is let down into the fermenting tun at a temperature varying from 55° to 70°, according to the quantity, the season, the goodness of the yeast, and the skill of the distiller. Here it is mixed successively with considerable portions of the best yeast that can be procured, and the fermentation is urged as far as it can be made to go. The process lasts about ten days, and the temperature rises usually to between 90° and 100°, and sometimes even higher. Great quantities of carbonic acid are disengaged, and the liquid becomes specifically lighter; sometimes sinking to 1·000, and usually to from 1·007 to 1·002. The success of the fermentation is estimated by this loss of specific gravity.

The wash thus prepared is distilled. What comes over first is denominated *low wine*, and is concentrated by a second distillation.

This fermentation is obviously the consequence of the action of the peculiar ferment in yeast upon the saccharine matter of the wort. Even when the fermentation is carried to its greatest extent, it does not appear that the whole solid matter held in solution by

* This is the name given to the fermented wort of distillers.

the wort is decomposed. Nine trials were made upon the wort of pure malt; in all of them the fermentation went on pretty successfully, as may be seen from the following table:—

Specific gravity of the wort.	Specific gravity of the wash.
1·0400	1·0014
1·0560	1·0016
1·0500	1·0000
1·0492	1·0012
1·0465	1·0045
1·0450	1·0047
1·0465	1·0007
1·0510	1·0007
1·0524	1·0004

When a portion of these different liquids was evaporated to dryness, the quantity of solid matter which it left was found to amount to $\frac{1}{3}$th, at an average, of the original quantity. Thus $\frac{4}{3}$ths had been decomposed by the fermentation, and $\frac{1}{3}$th still remained. This matter was still capable of fermentation, when redissolved in water and mixed with fresh yeast. On comparing the quantity of alcohol of 0·825, obtained in these trials, with the weight of solid matter of the malt which had been decomposed by the fermentation, the result was, that every pound weight of solid matter, so decomposed, furnished almost exactly half a pound of alcohol, of the specific gravity 0·825.

When sugar, dissolved in four times its weight of water, and mixed with yeast, is placed in the proper temperature, it ferments precisely as wort does, and yields the same products. It has been employed, therefore, by chemists as a less complicated means of ascertaining the phenomena of fermentation. Thenard mixed 60 parts of yeast with 300 of sugar, and fermented them in the temperature of 59°. In four or five days, he informs us, that all the saccharine matter had disappeared.* The quantity of carbonic acid evolved amounted, by weight, to 94·6 parts. It was perfectly pure, being completely absorbed by water.† The fermented liquid, being distilled, yielded 171·5 parts of alcohol, of the specific gravity ·822. When the residue of the distillation were evaporated, 12 parts of a nauseous acid substance were obtained; and 40 parts of the yeast still remained; but, upon examination, it had lost the whole of its azote. This experiment gives us the following quantities:—

* There is reason to doubt the precision of this assertion, as it never happens in the great scale, where every thing is much more favourable.

† The very pungent aromatic odour which carbonic acid has when disengaged from the fermenting tun, shows that it contains a portion of the wash; and this has been verified by actual experiment. Gay-Lussac has shown the quantity of alcohol carried off during the fermentation of wine. See Ann. de Chim. et de Phys. xviii. 380.

1. *Substances fermented.*

Sugar . . .	300
Yeast . . .	60
	360

2. *Products of fermentation.*

Alcohol of ·822 . .	171·5
Carbonic acid . . .	94·6
Nauseous residue . .	12·0
Residual yeast . . .	40·0
	318·1
Loss	41·9

But as the nauseous residue and residual yeast, nearly make up the quantity of yeast employed, let us consider only the products of decomposed sugar, supposing the loss to be proportionally divided between the carbonic acid and alcohol. Now, alcohol of the specific gravity 0·822 contains $\frac{1}{10}$th of its weight of water, which can be separated from it; and if we suppose, with Saussure, that absolute alcohol contains 8·3 per cent. of water, then the products of sugar decomposed by fermentation, according to the preceding experiment, are as follows:—

Alcohol	47·70
Carbonic acid . . .	35·34
	83·04

Or, in 100 parts

Alcohol	57·44
Carbonic acid . . .	42·56
	100·00

This result approaches so nearly that of Lavoisier, that there is reason to suspect that the coincidence is more than accidental.

We have found reason to conclude, that sugar of starch is composed of

9 atoms oxygen . .	= 9·000
$8\frac{1}{2}$ atoms carbon . . .	= 6·375
9 atoms hydrogen . .	= 1·125
	16·500

Alcohol is a compound of

1 atom oxygen . . .	= 1·000
2 atoms carbon . . .	= 1·500
3 atoms hydrogen . .	= 0·375
	2·875

And carbonic acid of

2 atoms oxygen . . .	= 2·00
1 atom carbon . . .	= 0·75
	2·75

Now, if we suppose 1 atom of sugar to be decomposed by the fermentation, it is obvious, that they may be converted into 3 atoms of alcohol and 3 atoms of carbonic acid. For an atom of sugar is composed of . . . . . $C^9\ H^9\ O^9$

3 atoms of alcohol consist of . . .	C^6	$H^9\ O^3$
3 atoms of carbonic acid of . . .	C^3	O^6
Making together	C^9	$H^9\ O^9$

On that supposition, the weight of the alcohol evolved ought to be . . . 5·75
And that of the carbonic acid . . . 5·50

Or, per cent.

Alcohol	51·12
Carbonic acid . . .	48·88
	100·00

Fabroni found that the gluten of wheat acted but imperfectly as a ferment; but that its efficacy was much improved by the addition of tartar. Berthollet repeated these experiments successfully. He ascribes the efficacy of tartar to the property which it has of promoting the solubility of the gluten. The presence of an acid was supposed formerly to be necessary for fermentation; but this does not seem to be the case. It is true, indeed, that an acid usually makes its appearance during fermentation. The formation of this acid has been ascribed to the action of the yeast upon the mucilaginous or starchy parts of the wort; but from the experiments of Fourcroy and Vauquelin, it appears that it always makes its appearance when wort is fermented without any yeast. In these trials they obtained only vinegar, and no alcohol. When the wort, either of raw grain or of malt, is fermented at the temperature of 80°, without any yeast, the gas which comes over consists of one-half carbonic acid and one-half hydrogen; but at a lower temperature, pure malt-wort does not yield any inflammable gas.*

SECTION II.—OF WINE.

There is a considerable number of ripe fruits from which a sweet liquor may be expressed, having at the same time a certain degree of acidity. Of such fruits we have in this country the apple, the cherry, the gooseberry, the currant, &c., but by far the most valuable of these fruits is the *grape*, which grows luxuriantly in the southern parts of Europe. From grapes, fully ripe, may be expressed a liquid of a sweet taste, to which the name of

* Ann. des Mus. d'Hist. vii. 16.

must has been given. This liquid is composed almost entirely of five ingredients; namely, *water*, *sugar*, *jelly*, *gluten*, and *tartaric acid* partly saturated with potash. The quantity of sugar which grapes, fully ripe, contain, is very considerable; it may be obtained in crystals by evaporating *must* to the consistence of syrup, separating the tartar which precipitates during the evaporation, and then setting the *must* aside for some months. The crystals of sugar are gradually formed.* From a French pint of *must*, the Marquis de Bouillon extracted half an ounce (French) of sugar, and $\frac{1}{10}$th ounce of tartar.† According to Proust, the Muscadine grape contains about 30 per cent. of a peculiar species of sugar.‡

When *must* is put into the temperature of about 70°, the different ingredients begin to act upon each other, and what is called *vinous fermentation* commences. The phenomena of this fermentation are an intestine motion in the liquid; it becomes thick and muddy, its temperature increases, and carbonic acid gas is evolved. In short, the very same changes take place as have been remarked when describing the fermentation of ale. In a few days the fermentation ceases, the thick part subsides to the bottom, or rises to the surface, the liquid becomes clear, it has lost its saccharine taste, and assumed a new one; its specific gravity is diminished; and it has become the liquid well known under the name of *wine*.

As this fermentation takes place without adding any *ferment*, it is obvious that the requisite substance is present in the juice. This substance was separated, and found by Fabroni to be analogous to the gluten of plants; and gluten being substituted for it, the fermentation succeeded. Fabroni has shown that the saccharine part of *must* resides in the cells of the grapes; while the glutinous matter, or ferment, is lodged on the membranes that separate the cells. Hence it follows, that in the fruit these two substances are not in contact. It is only after the juice is squeezed out that they are mixed. All other juices which undergo a spontaneous fermentation at the requisite temperature, have been shown by Thenard and Seguin to contain a similar substance. The formation of wine, then, is owing to the action of this glutinous matter on the saccharine substance of the juice, precisely as happens in the fermentation of ale.

Gay-Lussac has shown that the juice of grapes, and indeed the juice of all fruits will not ferment, if completely excluded from the air. But if a little oxygen gas be let up to it, this gas is immediately absorbed, a brisk fermentation commences, and the quantity of carbonic acid gas evolved is 100 times as great as that of the oxygen gas absorbed.§ It would be curious to know whether the same thing holds with repect to the wort of malt. It is not improbable that it does; but wort ferments so imperfectly without the addition of yeast, that it would not be easy to try the experiment.

* Bouillon, Jour. de Phys. xxix. 3. † Ibid. p. 5. ‡ Ibid. lvi. 113.
§ Ann. de Chim. lxxvi. 245.

All those juices of fruits which undergo the vinous fermentation, either with or without the addition of sugar, contain an acid. We have seen already that the vegetable acids are obtained chiefly from fruits. The apple, for instance, contains malic acid; the lemon, citric acid; the grape, tartaric and malic acids. The Marquis de Bouillon has ascertained that *must* will not ferment if all the tartar which it contains be separated from it; but it ferments perfectly well on restoring that salt.* The same chemist ascertained that the strength of wine is considerably increased by adding tartar and sugar to the *must*.† We may conclude from these facts, that the presence of a vegetable acid is of importance in these spontaneous fermentations. It deserves attention, that Bouillon obtained more tartar from verjuice than from wine; and he observed, that the more the proportion of sugar in grapes increased, the more that of tartar diminished.‡

It seems more than probable, from the experiments of Bouillon and Chaptal, that the tartaric acid is partly decomposed during the fermentation, and that a portion of malic acid is formed. The process, therefore, is more complicated than was suspected by Lavoisier. It is obviously analogous to combustion, as is evident from the evolution of caloric and the formation of carbonic acid, which is a product of combustion. Proust has affirmed that, during the fermentation, not only carbonic acid, but azotic gas also, is disengaged. This, supposing it correct, is a demonstration that all the constituents of *must* are concerned; for sugar does not contain that principle.§ Thenard could detect no azote in the carbonic acid from wort.

After the fermentation has ceased, the liquor is put into casks, where the remainder of the sugar is decomposed by a slow fermentation; after which the wine, decanted off the extractive matter, is put up in bottles.

The properties of wine differ very much from each other, according to the nature of the grapes from which the *must* was extracted, and according to the manner in which the process was conducted. These differences are too well known to require a particular description. But all wines contain less or more of the following ingredients; not to mention water, which constitutes a very great proportion of every wine.

1. *An Acid.* All wines give a red colour to paper stained with turnsole, and of course contain an acid. Chaptal has ascertained that the acid found in greatest abundance in wine is the malic, but he found traces also of citric acid; and it is probable that wine is never entirely destitute of tartar. All wines which have the property of frothing when poured into a glass contain also carbonic acid, to which they owe their briskness. This is the case

* Jour. de Phys. xxix. 4. But the addition of salt of wood sorrel did not restore the fermentation.

† Ann. de Chim. xxxvi. 20.

‡ Jour. de Phys. xxix. 4.

§ Ibid. lvi. 113.

with champagne. These wines are usually weak; their fermentation proceeds slowly, and they are put up in close vessels before it be over. Hence they retain the last portions of carbonic acid that have been evolved.

2. *Alcohol.* All wine contains less or more of this principle, to which it is indebted for its strength; but in what particular state of combination it exists in wine cannot easily be ascertained. It is undoubtedly intimately combined with the other component parts of wine; but Mr Brande has shown by very decisive experiments that all wines contain alcohol ready formed, and that it is merely separated during the distillation of these liquids, and not formed as had been advanced by Fabroni.* These experiments were afterwards confirmed by Gay-Lussac.† When wine is distilled, the alcohol readily separates. The distillation is usually continued as long as the liquid which comes over is inflammable. The quantity obtained varies according to the wine, from a fourth to a fourteenth part of the wine distilled. The spirit thus obtained is well known under the name of *brandy*. Bouillon has observed, that when wine is distilled new it yields more alcohol than if it be allowed to get old.‡ What remains after this distillation is distinguished in France by the name of *vinasse*. It consists of tartar, &c., and when evaporated to dryness, and subjected to combustion, yields potash.

3. *Extractive matter.* This matter exists in all wines: but its proportion diminishes according to the age of the wine, as it gradually precipitates to the bottom.

4. Every wine is distinguished by a peculiar flavour and odour, which probably depends upon the presence of a *volatile oil*, so small in quantity that it cannot be separated.

5. The *colouring matter* of wine is originally contained in the husk of the grape, and is not dissolved till the alcohol be developed. This matter is analogous to the other colouring matters of plants: a set of bodies possessed of remarkable properties, but too little examined hitherto to be introduced with much advantage into a System of Chemistry. This colouring matter precipitates when the wine is exposed to the heat of the sun. It sometimes also precipitates in old wine, and it may be easily separated by pouring lime-water into wine.§

From the experiments of Vogel, it appears that the colouring matter of red wine is precipitated greenish-grey by acetate of lead. By this property we can distinguish whether a red wine be genuine or factitious.‖

The following table, containing the different substances which Neumann extracted from various wines, is worth preserving:—¶

* Phil. Trans. 1811, p. 337; and 1813, p. 82.

† Ann. de Chim. lxxxvi. 175. ‡ Jour. de Phys. xxix. 6.

§ The most precise account of wine and of the vinous fermentation, hitherto published, is by Chaptal, and is contained in the 36th and 37th volumes of the Ann. de Chim.

‖ Annals of Philosophy, xiii. 70. ¶ Neumann's Chemistry, p. 447.

A quart of	Highly rectified Spirit.			Thick, oily, unctuous, resinous matter.			Gummy and tartarous matter.			Water.			
	oz.	dr.	gr.	oz.	dr.	gr.	oz.	dr.	gr.	lb.	oz.	dr.	gr.
Aland . .	1	6	00	3	2	00	1	5	00	2	5	3	00
Alicant . .	3	6	00	6	0	20	0	1	40	2	2	6	00
Burgundy .	2	2	00	0	4	00	0	1	40	2	9	0	20
Carcassone .	2	6	00	0	4	10	0	1	20	2	8	4	30
Champagne .	2	5	20	0	6	40	0	1	00	2	8	3	00
French . .	3	0	00	0	6	40	0	1	00	2	8	0	20
Frontignac .	3	0	00	3	4	00	0	5	20	2	4	6	30
Vin de Grave	2	0	00	0	6	00	0	2	00	2	9	0	00
Hermitage .	2	7	00	1	2	00	0	1	40	2	7	5	20
Madeira .	2	3	00	3	2	00	2	0	00	2	4	3	00
Malmsey .	4	0	00	4	3	00	2	3	00	2	1	2	00
Vino de Monte Pulciano	2	6	00	0	3	00	0	2	40	2	8	0	20
Moselle . .	2	2	00	0	4	20	0	1	30	2	9	0	10
Muscadine .	3	0	00	2	4	00	1	0	00	2	5	4	00
Neufchatel .	3	2	00	4	0	00	1	7	00	2	2	7	00
Palm Sec. .	2	3	00	2	4	00	4	4	00	2	2	5	00
Pontac . .	2	0	00	0	5	20	0	2	00	2	9	0	40
Old Rhenish	2	0	00	1	0	00	0	2	20	2	8	5	40
Rhenish . .	2	2	00	0	3	20	0	1	34	2	9	1	06
Salamanca .	3	0	00	3	4	00	2	0	00	2	3	4	00
Sherry . .	3	0	00	6	0	00	2	2	00	2	0	6	00
Spanish . .	1	2	00	2	4	00	9	4	00	1	10	6	00
Vino Tinto .	3	0	00	6	4	00	1	6	00	2	0	6	00
Tokay . .	2	2	00	4	3	00	5	0	00	2	0	3	00
Tyrol red wine	1	4	00	1	2	00	0	4	00	2	8	6	00
Red wine .	1	6	00	0	4	40	0	2	20	2	9	3	20
White . .	2	2	00	0	7	00	0	3	00	2	7	0	00

To this head belong not only common wine, but all the intoxicating liquors made from vegetable juices; as *cyder* from apples, *perry* from pears, *currant* wine, &c., likewise the liquor made from the juice of the sugar cane, the sugar maple, &c.

I shall here subjoin a table of the quantity of alcohol by measure of the specific gravity 0·825, which different wines yielded to Mr Brande in his different experiments. The results of these trials are the more valuable, because the wines examined were all genuine.*

* Phil. Trans. 1811, p. 345; 1813, p. 87. Journal of the Royal Institution, i. 136.

	Alcohol per cent. by measure.		Alcohol per cent. by measure.
Lissa	26·00	Marsala	26·30
Ditto	24·00	Ditto	25·50
Port	21·40	Red Champagne	11·30
Ditto	22·30	White Champagne	12·80
Ditto	23·39	Burgundy	14·53
Ditto	23·71	Ditto	11·95
Ditto	24·29	White Hermitage	17·43
Ditto	25·83	Red Hermitage	12·32
Ditto	21·40	Hock	14·37
Ditto	19·00	Ditto	8·88
Madeira	19·34	Vin de Grave	12·80
Ditto	21·40	Frontignac	12·79
Ditto	23·93	Cote Roti	12·32
Ditto	24·42	Rousillon	17·26
Sherry	18·25	Cape Madeira	18·11
Ditto	18·79	Cape Muschat	18·25
Ditto	19·81	Constantia	19·75
Ditto	19·83	Tent	13·30
Claret	12·91	Sheraaz	15·52
Ditto	14·08	Syracuse	15·28
Ditto	16·32	Nice	14·63
Calcavella	18·10	Tokay	9·88
Lisbon	18·94	Raisin Wine	25·77
Malaga	17·26	Grape Wine	18·11
Ditto, kept since 1666	18·00	Currant Wine	20·55
Bucellas	18·49	Gooseberry Wine	11·84
Red Madeira	18·40	Elder Wine	9·87
Malmsey Madeira	16·40	Cyder	9·87
Marsala	25·87	Perry	9·87
Ditto	17·26		

Every body knows that wine has a peculiar smell, by which it is easily known, and by which it is at once distinguished from a mixture of alcohol and water, of the same strength with the wine. This smell is owing to the presence of a small quantity of a peculiar substance, analogous in its properties to a volatile oil. It amounts, at an average, to about $\frac{1}{40,000}$th part of the wine. When a great quantity of wine is distilled, this substance passes over towards the end of the distillation. It may be obtained also by distilling the lees of wine, particularly what is deposited at the bottom of the wine casks when the wine begins to ferment. When pure it is colourless. Liebeg and Pelouze have lately examined this substance, with which they were furnished by M. Deleschamps, and they have found it to be a peculiar ethereal liquid to which they gave the name of *œnanthic ether*.*

An account of the properties and composition of this ether has been given in a preceding Chapter of this volume.†

* Ann. de Chim. et de Phys. lxiii. 113.

† See p. 341.

CHAPTER II.

OF THE PANARY FERMENTATION.

The method of making loaf bread similar to ours, was known in the East at a very early period; but neither the precise time of the discovery, nor the name of the person to whom mankind is indebted for it, has been handed down to us. That the Jews knew how to make bread in the time of Moses, or above 1600 years before the commencement of the Christian era, is evident from the prohibition of the use of leavened bread during the celebration of the passover.* There is no evidence that loaf bread was known to Abraham; for in his history, cakes are frequently mentioned, but loaf bread, or leavened bread, never. It can scarcely be doubted, that the Jews learned the art of making loaf bread from the Egyptians. The Greeks inform us, that they were taught the method of making loaf bread by the god Pan. We learn from Homer, that loaf bread was known during the Trojan war.† Pliny informs us, that no bakers existed in Rome till the year 580 after the building of the city, or about 200 years before the commencement of the Christian era. Before that time, bread was made in private houses, and was the business of the women.‡

The only substance fit for making good loaf bread is wheat flour, obtained by grinding the seeds of *triticum hybernum*, and probably other species of *triticum*. The nature of the constituents of wheat flour, so far as ascertained, has been stated in a former Chapter of this volume.

It is the practice in some places to mix wheat flour with potatoe starch. Such an addition cannot exceed 30 per cent., otherwise the flour would not be fit for making bread. M. Boland, a baker in Paris, has given the following method of detecting the presence of potatoe starch, when thus mixed with flour:—

Take about 300 grains of the flour, make it into a paste, and, kneading it under a small stream or thread of water, separate the gluten which remains in the hand. The water falls on a cloth stretched on the wide end of a funnel, corked at its narrow end. The cloth retains the gluten, and the water with the starch falls into the funnel. Let the starch subside from the water in the funnel, then decant off the water by a syphon or sucker. Let the starch dry: it will be observed to consist of two layers; the uppermost is grey, and consists of gluten, the undermost of starch. Detach the dry starch from the funnel without breaking the lump. Take the lowest portion, triturate it with water in a mortar, filter,

* Exod. xii. 15.

† Πατροκλος μιν σῖτον ἑλων επινιμε τραπεζῃ. Iliad, lib. ix. l. 216.

‡ Plinii Hist. Nat. xviii. cap. 11.

and add a drop of tincture of iodine. If it be potatoe starch, (as it will be, if any be present,) the iodine strikes a fine blue. If no potatoe starch be present, the liquid becomes only yellow or violet red, which soon disappears. By repeating this trial on new slices of the starch, you can determine how much potatoe starch it contains.*

The process of baking bread consists in mixing wheat flour with water, and forming it into dough. The average proportion is, two parts of water to three of flour, by weight. But this proportion varies considerably, according to the age and quality of the flour. In general, the older and the better the flour is, the greater is the quantity of water required. If the dough, after being thus formed, be allowed to remain for some time, the sugar undergoes a fermentation, being decomposed into carbonic acid and alcohol. The gluten which exists in every part of this dough, prevents the carbonic acid gas from escaping. It therefore heaves up the dough in every part, and more than doubles its bulk. The fermentation, however, does not stop when the sugar is decomposed. It continues to act upon the alcohol, and gradually converts it into acetic and lactic acids. The consequence of this last action, which cannot be prevented on account of the slowness of the vinous fermentation of the dough, is, that it acquires a sour taste and smell; and if it be baked in the oven, though the loaf is full of eyes, and possesses the characters of loaf bread, yet its acid taste and smell render it disagreeable to the palate, and unfit for the purposes of food. Dough that has been allowed to ferment in this way is called *leaven*.

But if a small quantity of this leaven be mixed with new made dough, and the mixture laid aside for a few hours, fermentation commences, and goes on much more rapidly, so that the dough swells to at least twice its original bulk. If it be now put into the oven and baked, the fermentation is checked before any acid begins to be formed, and the bread is full of eyes, light, spongy, and sweet.

The ancient Gauls and Spaniards, as we are informed by Pliny, contrived another method of bringing on a fermentation in dough. Instead of *leaven*, they added to the dough a quantity of the *yeast* or *barm*, which collects on the surface of fermenting beer.† This addition occasions fully as speedy a fermentation as leaven, and it is not nearly so apt to give the bread a sour flavour. About the end of the 17th century, the bakers of Paris began to substitute yeast for leaven. The practice was discovered and exclaimed against. The faculty of medicine, in 1688, declared it prejudicial to the health; and many years elapsed before the bakers were able to convince the public that bread raised by means of yeast is better than that fermented by leaven. Barm is now employed in preference to leaven in every civilized country. In this country the yeast used by the bakers is made artificially, chiefly from potatoes.

* See Jour. de Pharmacie, xxii. 305.

† Plinii Hist. Nat. lib. xviii. c. 7. Galliæ et Hispaniæ frumento us potum resoluto quibus diximus generibus, spuma ita concreta pro fermento utuntur.

The process followed by our bakers is nearly as follows :—

A certain quantity of salt is dissolved in water, the temperature of which varies, according to circumstances, from 70° to 100°. Yeast is mixed with this water, and then a portion of flour is added, but always less than is ultimately employed in forming the finished dough. The mixture is covered up and set apart in a warm place. Fermentation begins to be evident in about an hour. The *sponge* (so the imperfect dough is called) begins to swell up in consequence of the evolution of carbonic acid gas. This gas, being confined by the adhesive nature of the gluten, heaves up the sponge to twice its original bulk. Being no longer capable of containing this pent up gas, it bursts and subsides. This alternate rising and falling of the sponge might be repeated a great many times. But unless the baker stops it after the second, or, at the utmost, the third dropping of the sponge, the bread invariably proves sour.

He therefore, at this period, adds to the sponge the remaining quantity of flour, water, and salt, and incorporates these new materials with the sponge, by a long and laborious course of kneading. After this the dough is left to itself for a few hours, during which time it continues in a state of active fermentation, diffused through every part of it. It is then subjected to a second, but much less laborious kneading, in order to distribute the imprisoned gas as equally as possible through the whole dough. It is now weighed out into the portions requisite to form the kinds of bread desired. These portions are shaped into loaves, and set aside for an hour or two in a warm situation. The fermentation still goes on, and gradually expands the mass to double its former bulk. They are now put into the oven and baked into loaves.

The mean heat of a baker's oven, as ascertained by M. Tillet, is 448°.* The bakers do not use a thermometer, but judge that it has arrived at the proper heat when flour, thrown on the floor of it, becomes black very soon without taking fire. This heat immediately stops the fermentation, but the gas already generated is swelled out by the heat, and gives the loaf its characteristic vesicular structure.

When bread is taken out of the oven it is lighter than when put in, from the evaporation of a portion of moisture during the baking. It would appear also, from the analysis of bread by M. Vogel, that a portion of the starch is converted into sugar. A few years before the beginning of the French Revolution, the French bakers petitioned their goverment to investigate the loss of weight which bread sustains in the oven, alleging that the loss was very various, and that, on that account, they had been frequently taxed with dishonesty without reason. M. Tillet and the other commissioners appointed to investigate the subject, in consequence of this petition, found that a loaf, which weighed, before it was put into the oven, 4·625 lbs., was reduced, at an average, to 3·813 lbs.; so that it

* Encyc. Method. Arts et Metiers, i. 275.

lost 17·54 per cent. of its original weight. This somewhat exceeds $\frac{1}{6}$th of the original weight of the dough. They found, however, that this loss of weight was by no means uniform, even when the nature of the dough, the heat of the oven, the situation of the loaves, and every other appreciable circumstance was exactly the same. The difference amounted in some cases to $7\frac{1}{2}$ per cent. Other things being the same, the loss of weight sustained is proportional to the extent of surface of the loaf, and to the length of time that it remains in the oven. A loaf was weighed after being baked, and was found to weigh exactly 4 lbs. Being replaced in the oven for ten minutes and then weighed again, it weighed $\frac{1}{8}$th of a lb. less than before. Being put again into the oven for ten minutes, it sustained an additional loss of weight amounting to $\frac{1}{16}$th of a lb.*

Loaves are heaviest when just taken out of the oven. Unless they be kept in a damp place or wrapt round with a wet cloth, they gradually lose weight. Thus Tillet found that a loaf weighing at first 4 lbs. had lost, after being kept a week, about $\frac{1}{13}$th of its original weight. New baked bread possesses a peculiar taste and smell, which it loses by keeping, unless it be wrapt round with a wet towel. In that case much of the taste and smell are preserved.

Instead of yeast, bakers sometimes have recourse to sesquicarbonate of ammonia, to render their bread porous. Somewhat more than a quarter of an ounce of this salt for every pound of flour employed is dissolved in the requisite quantity of water for converting the flour into dough. After the whole dough is well kneaded, it is divided into loaves and baked in the oven. The heat expands the salt into gas, and gradually forces it out of the dough. But it remains long enough to fill the loaf full of eyes, and thus to render it sufficiently porous. While hot it still gives out the smell of ammonia, showing that the whole of the salt has not made its escape; but the quantity remaining is too small to affect the taste of the loaf.

It appears from the experiments of Dr H. Colquhoun that when the flour is mixed with sesquicarbonate of soda, or carbonate of magnesia in fine powder, and made into a dough with water, holding in solution the requisite quantity of tartaric acid, to saturate the soda or magnesia employed, the dough becomes loose, light, and spongy to a considerable degree. But the bread baked from it proved doughy and sad, and contained but few vesicles.†

The mode of rendering *gingerbread* vesicular, or of inducing in it the requisite panary fermentation, deserves to be described. The ingredients of gingerbread are *flour*, *treacle*, *butter*, *pearl ashes*, (or carbonate of potash) and *alum*. After the butter is melted and the potash and alum are dissolved in a little warm water, these three ingredients along with the treacle are poured among the flour which is to form the basis of the bread. The whole is then incorporated together into a stiff dough, the alum makes the bread lighter and

* Encyc. Method. Arts et Metiers, i. 270.
† Annals of Philosophy, (Second Series), xii. 267.

crisped; but its introduction may be dispensed with. The treacle acts slowly upon the potash, and gradually expels the carbonic acid which renders the dough vesicular. But the process is very slow. The dough must remain three or four days to eight or ten days before enough of gas has been extricated to render the dough fit for being baked. Indeed it has been found that it may stand even several weeks rather with advantage than with loss in this respect.

Dr Colquhoun found that if carbonate of magnesia be substituted for pearl ashes in gingerbread, and the requisite quantity of tartaric acid to saturate the magnesia be kneaded into the dough, the gingerbread is as well raised or as vesicular as when potash is used and it is fit for being baked within an hour after being formed.* The gingerbread made in this way is superior to that made by the baker's process, because it is free from the large portion of alkali which common gingerbread contains, and which renders it injurious when eaten in any quantity. The proportions which Dr Colquhoun found best are the following:—

Flour	1 pound
Butter	3 ounces
Sugar or treacle . . .	2 ounces
Carbonate of magnesia . .	$\frac{1}{4}$ ounce
Tartaric acid . . .	$\frac{1}{8}$ ounce

He found that if potashes be used, and the requisite quantity of sulphuric acid to saturate the alkali be added, the gingerbread may be baked in the oven in a very short time after the dough has been kneaded. But the gingerbread formed in this way has a taste decidedly bitter.

CHAPTER III.

OF THE ACETOUS FERMENTATION.

If wine or beer be kept in a temperature between 70° and 90°, while atmospheric air has access to it or some fermenting principle is present, it gradually becomes thick, its temperature augments, filaments are seen moving through it in every direction, and a kind of hissing noise may be distinguished. These intestine motions gradually disappear, the filaments attach themselves to the sides and bottom of the vessel, and the liquor becomes transparent. But it has now lost its former properties, and is converted into acetic acid. This intestine decomposition has been long distinguished by the name of *acetous fermentation*, because its product is *acetic acid*.

* Annals of Philosophy (Second Series), xii. 275.

That this fermentation may take place, certain conditions must be attended to. The most important of these will appear from the following observations :—

1. Neither pure alcohol, nor alcohol diluted with water, is susceptible of this change. The weaker the wine or the beer is on which the experiment is made, the more readily it is converted into vinegar : the stronger they are they resist the change with the greater obstinacy. But it results from the experiments of Beecher, that strong wines when they are made to undergo the acetous fermentation, yield a much better and stronger vinegar than weak wines. Hence it follows that alcohol, though of itself it refuses to undergo the change, yet when other bodies are present which readily ferment, is decomposed during the process, and contributes to the formation of the acetic acid.*

2. Wine, entirely deprived of glutinous matter, either by spontaneous deposition or by clarification, does not undergo the acetous fermentation, unless some mucilaginous matter be mixed with it. Chaptal exposed old wine destitute of this matter, in open bottles, to the greatest summer heat of Montpelier for 40 days, and yet it did not become sour : but upon adding some vine leaves to the same wine, it became acid in a few days.† When the water in which gluten of wheat has been allowed to ferment is mixed with sugar, the liquid is converted into vinegar without fermentation, without effervescence, and without the contact of air.‡ The nature of this curious change has not been explained.

3. Wine never becomes sour, provided it be completely deprived of all access to atmospheric air. In order to understand what takes place during the conversion of alcohol into acetic acid, we have only to attend to the constitution of these two bodies. Alcohol is $C^4\ H^5\ O + H\ O$ while acetic acid is $C^4\ H^3\ O^3 + H\ O$. The first thing that happens is the absorption of two atoms of oxygen from the atmosphere for every integrant part of alcohol present. These combine with two atoms of hydrogen and form water, leaving the alcohol in the state of $C^4\ H^3\ O + H\ O$. Now this is aldehyde. The aldehyde has a strong affinity for oxygen. It absorbs two atoms of it from the atmosphere, and is converted into $C^4\ H^3\ O^3 + H\ O$, or acetic acid. From this it appears, that during the conversion of alcohol into acetic acid, every atom of alcohol absorbs 4 atoms of oxygen from the atmosphere. Hence unless the atmospherical air be constantly renewed, the process of acetification cannot go on. Even when the process is properly conducted about $\frac{1}{15}$th of the whole acetic acid formed is lost. But when the air is not sufficiently renovated to enable the aldehyde to absorb oxygen as fast as it is formed, a great deal of it is volatilized, and the consequent loss of

* These opinions have been confirmed by the experiments of the Commission appointed by the Paris Society of Pharmacy, to examine the Prize Essays given in on the Theory of Acetification. See Jour. de Pharmacie, xviii. 364.

† Ann. de Chim. xxxvi. 245.

‡ Fourcroy and Vauquelin, Ann. de Mus. d'Hist. Nat. vii. 4.

acetic acid may be very great. This sufficiently shows the necessity on the part of the vinegar manufacturers of producing a perpetual renovation of air in their chambers.

4. A pretty high temperature is necessary for the commencement of the acetous fermentation. Wine or beer (unless very weak) scarcely becomes sour under the temperature of 65° or 70°. The fermentation is very apt to commence when the temperature suddenly rises. It is said, too, that wine and beer are more apt to become sour at certain seasons of the year than at others.

The vinegar makers in this country keep their wash in stoves, heated to about the temperature of 80°, till the change is completed. From the experiments of Fourcroy and Vauquelin, it appears that vinegar made from grain holds in solution a quantity of gluten, and that a great part of it is separated by heating the vinegar boiling hot. This separation prevents the vinegar from being so apt to spoil.

5. When the acetous fermentation is completed, the whole of the malic acid originally contained in the wine has disappeared as well as the alcohol. We must conclude, therefore, that they have been both converted into acetic acid. Part of the glutinous matter has also undergone the same change, and seems indeed to have been the substance that first began the change. Part of it is deposited in the state of flakes; part remains in solution, and disposes the vinegar to decomposition. Vinegar also contains a little tartar, and probably also citric acid. Malic acid is also found in new vinegar; a proof that this part of the wine is the last to undergo the acetous fermentation.

6. From the experiments of Cadet it appears, that sugar is the essential constituent in liquors to be converted into vinegar, and that the quantity of vinegar formed is proportional to the sugar. But if the sugar exceed $\frac{1}{8}$th part of the liquid, the whole is not decomposed. Seven water, one sugar, and some yeast ferment in a proper temperature, and form an excellent vinegar.*

7. Acetic acid is formed in many other cases of the decomposition of vegetables besides the acetous fermentation. These have been pointed out with much ingenuity by Vauquelin and Fourcroy.

They may be reduced under three heads. First, when sugar, gum, wood, &c., are distilled in a retort, or even burnt in the open fire, acetic acid separates in combination with an empyreumatic oil, which gives it a peculiar odour. Hence it was mistaken for other acids, and distinguished by the name of *pyroligneous acid*, &c., till its real nature was ascertained by these distinguished chemists.† Secondly, when concentrated sulphuric acid is poured upon the same vegetable bodies, they are decomposed in a very different manner; being converted into water, charcoal, and acetic acid. Thirdly, acetic acid is evolved in considerable quantity during the spontaneous decomposition of urine and some other animal substances. Thus it appears that the component parts of acetic acid are extremely apt

* Ann. de Chim. lxii. 248. † Ibid. xxxv. 83.

to combine together in those proportions which constitute that important acid.

CHAPTER IV.

OF PUTREFACTION.

VEGETABLE substances, both complete plants and their component parts taken separately (the strong acids, the alkalies, resins, fixed and volatile oils excepted), are gradually decomposed and destroyed, provided moisture be present, and provided atmospherical air have access to them, and the temperature be not much under 45°, nor so high as to drive off all the moisture. This decomposition has obtained the name of *putrefaction*, a name obviously derived from the disagreeable smell given out during the process. No chemist has hitherto attempted to ascertain the nature of the changes which go on during this spontaneous decomposition. I can only offer a few general observations on the subject.

1. When vegetable substances are dried, and kept dry, putrefaction does not take place. It is doubtless owing to the abstraction of moisture, that alcohol, sugar, and common salt have the property of preventing vegetable bodies immersed in them from putrefying.

2. It would appear that plants do not putrefy *in vacuo*, or at least the alteration goes on very slowly. Every body knows the method employed in this country for preserving green peas for the table during the winter and spring months, before they can be procured from gardens. A clean dry bottle is filled with the peas to be preserved. It is then corked so as to be completely air tight. It is afterwards plunged in boiling water, and kept at that temperature for some time. The peas at that temperature absorb the oxygen from the small quantity of common air contained in the bottle, and as the bottle is air tight a partial vacuum is formed within it, and continues till the bottle is opened. Under these circumstances the peas may be kept for a whole year perfectly fresh. When dressed they are rather harder than peas just from the garden, but in every other respect they could not be distinguished from new pulled peas.

It is on the same principle, that vegetables are sometimes preserved by being covered over with melted butter or with oil. And that seeds are often brought to this country from a great distance, by being surrounded with a covering of melted tallow.

3. When vegetables putrefy in the open air they absorb oxygen gas. But in general they emit a volume of carbonic acid gas equal to that of the oxygen absorbed. From the experiments of Saussure, we learn, that when moist wood is left exposed to the air, a portion of the oxygen of the atmosphere is converted into carbonic acid; for the quantity of this acid formed is just equal to the bulk of the

oxygen which disappears. When the experiment is made under receivers, no other gas can be detected except carbonic acid; but in the open air the wood loses a much greater proportion of its weight than can be accounted for by the carbon thus abstracted. This he ascribes to the escape of oxygen and hydrogen under the form of water. Hence the quantity of carbon in a given weight of rotten wood is greater than in the same weight of fresh; but when the putrefaction goes on in water without the contact of air, the wood becomes white and light, and contains a smaller proportion of carbon than when fresh.*

4. When moist vegetable matter, *hay*, for example, is accumulated in quantities during hot weather, a remarkable phenomenon takes place. Oxygen gas is absorbed very rapidly and converted into carbonic acid, while at the same time the temperature augments, at first slowly, but afterwards with rapidity, and unless the action be checked, by spreading out the vegetable matter to dry, combustion ensues. In this way, it is well known, that hay stacks are sometimes destroyed, when the hay has been built into stacks before it was fully dry. In this way cotton has been known to catch fire of itself. When linen or hemp is left in contact with the drying oils, the same absorption of oxygen, and the same augmentation of temperature frequently ending in combustion takes place. In this way a frigate was consumed at Cronstadt, in the year 1781. The fire proceeded from a mixture of lamp black and linseed oil that had been mixed up to paint the vessel, and had been left covered with linen.† The heat produced by the putrefaction of moist oak bark taken out of the tan pit, has been long known, and is in familiar use with gardeners and white lead makers, to raise heat enough to answer the respective purposes which they have in view.

5. When vegetable substances are composed of carbon, hydrogen, and oxygen only, the smell which they emit during putrefaction is not offensive. But when azote is present also, the gases given off have a very disagreeable odour. Hence the reason of the very offensive smell given out during the putrefaction of the cruciform plants, cabbages for example. Onions also for the same reason are very offensive during their putrefaction. And when vegetables besides azote, contain also sulphur and phosphorus, the smell which they give out while putrefying is most abominable.

6. When vegetable bodies (the leaves of trees, &c.) putrefy on the surface of the ground, they at last leave a blackish-brown powder, to which the name *humus* or *vegetable soil* has been given. A quantity of this soil is formed every year by the putrefaction of the withered leaves, &c., which are deposited on the earth at the beginning of winter. This *humus* mixing with the earthy matter of which the soil of vegetables chiefly consists, serves as a manure to nourish future vegetables. This *humus* consists chiefly of the extractive matter to which Berzelius has given the name of *apotheme*, and

* Recherches Chimique sur la Vegetation. † Jour. de Phys. xx. 1.

which has been described in a preceding Chapter of this work. The *apotheme* in an analysis of the humus of wheat amounted to about 26½ per cent. It dissolved in potash ley. What remained undissolved, when treated with muriatic acid, gave lime, peroxide of iron, and phosphate of lime, and then dissolved in a great measure in potash ley, leaving about 30 per cent. of charcoal, or a black combustible matter insoluble in reagents. Boullay, junior, subjected this apotheme to analysis, and obtained the very same constitution as that of gallic acid. He found the compound which it forms with oxide of copper (for it possesses the characters of an acid) composed of

Apotheme . . .	89·5 or 42·61
Oxide of copper . .	10·5 or 5
	47·61

This would make the atomic weight 42·6. But the atomic weight of gallic acid is 10·625, and it is composed of C^7 H^3 O^5. It is obvious from this, that the acid of humus called *ulmic* acid by Braconnot, and *geic* acid by Berzelius is composed of

28 atoms carbon . . .	= 21
12 atoms hydrogen . .	= 1·5
20 atoms oxygen . . .	= 20
	42·5

and that its true atomic weight is 42·5.

From the experiments of Saussure, we learn, that when the insoluble charry matter of humus is left exposed to the air, it gradually absorbs oxygen gas, which converts it into carbonic acid, and by this diminution of carbon it becomes soluble in water, and assumes the characters of the acid of humus.

APPENDIX.

THE two following acids were accidentally omitted. The first ought to have been inserted after page 62, as will be obvious from inspecting the table of fixed acids in page 52; the second should have been inserted after Section 6th, in page 63.

OF CITRICIC ACID.

Should have come in after Pyrocitric, in page 62.

This acid, which has been recently discovered by M. Baup, is formed when citric acid crystals are distilled.*

To obtain it, the liquid which comes over when citric acid is distilled, is evaporated by a very gentle heat. The liquid being allowed to cool, the crystals of pyrocitric acid deposited are removed, and the process continued till small needle-form crystals begin to make their appearance. From this moment, all the crystals deposited are set apart, in order to obtain from them the new acid, by dissolving them again in water and crystallizing a second time. The separation is easy on account of the great difference in the solubility of the two acids.

Citricic acid thus obtained, is destitute of smell, but has a strongly acid taste. The crystals are usually octahedrons, consisting of two four-sided pyramids, with a rhomboidal base. The primary form is a right rhombic prism. The adjacent faces of the two pyramids, constituting the octahedron, meet at angles of 136° 20′; while the pyramidal faces make with each other angles of 124° and 73° 15′. These crystals cleave easily into brilliant plates, parallel to the plane passing through the obtuse pyramidal faces of the octahedron.

Citricic acid, at 50°, is soluble in 17 times its weight of water: at 68° it requires only 12 times its weight to dissolve it. Its solubility increases greatly with the temperature, and on that account a concentrated hot solution crystallizes on cooling. At 59° degrees it dissolves in 4 times its weight of alcohol, of the specific gravity 0·827. It is soluble also in ether.

Though heated to 212°, or even to 248°, it loses no weight. At 322° it fuses into a colourless liquid, which crystallizes in plates on cooling. Just before it melts, it begins to exhale white irritating vapours, which have a peculiar smell. These vapours are condensed into white needle-form crystals. If we continue the heat, the whole acid is volatilized, without leaving any charry residue whatever, provided the heat has been cautiously applied.

* Ann. de Chim. et de Phys. lxi. 182.

To determine the atomic weight of this acid, M. Baup analyzed a quantity of anhydrous citricate of silver. 100 grains of this salt yielded 62·73 grains of silver, equivalent to 67·39 grains of oxide of silver. Hence the salt is composed of

Citricic acid . .	32·61	or 7·01
Oxide of silver . .	67·39	or 14·5
	100·00	

We see, from this analysis, that the atomic weight of the acid is 7, which is precisely the same with that of pyrocitric acid. He found it also isomeric; for an ultimate analysis of the salt of silver with oxide of copper gave

Carbon . . .	53·572
Hydrogen . .	3·571
Oxygen . . .	42·857
	100·00

Sensibly the same with the results obtained by Dumas, from the analysis of pyrocitric acid. The constituents, of course, must be

5 atoms carbon . . .	= 3·75
2 atoms hydrogen . . .	= 0·25
3 atoms oxygen . . .	= 3
	7·00

The crystals of this acid contain 1 atom of water; or they are composed of

1 atom citricic acid . . .	7
1 atom water	1·125
	8·125*

Citricic acid precipitates the acetate and subacetate of lead, and gives to the salts of peroxide of iron a red colour. The citricates occasion white precipitates also, when dropt into nitrate of lead, nitrate of silver, or nitrate of mercury. They throw down a red precipitate from the persalts of iron.

The citricates have a disposition to form supersalts, but this is not so strong as it is in the pyrocitrates.

1. *Citricate of ammonia.* This salt does not crystallize. When exposed to heat, it gradually loses ammonia, and is converted into bicitricate, which is capable of crystallizing. There are two bicitricates differing from one another in the water of crystallization.

The first is obtained, when the salt is crystallized, at the temperature of 68°, or a little below it, provided the solution be very concentrated, or that a crystal of the salt is put into the bottom of the vessel to hasten the crystallization. The crystals are transparent tables or prisms, not altered by exposure to the air; and, at the temperature of 53°½, they dissolve in 1½ times their weight of water. The constituents of this salt are

* The name citricic acid, was given by M. Baup, because he thinks that the nomenclature of isomeric bodies should be improved. He proposes to distinguish them by the consonants, taken in the alphabetic order. Thus, the first discovered body isomeric with his, is the pyrocitric of Lassaigne. He proposes to call it citri*b*ic acid; his own he calls citricic; should a third be discovered, it would be called citri*d*ic; a fourth, citri*f*ic, and so on.

2 atoms citricic acid . .	14
1 atom ammonia . . .	2·125
2 atoms water . . .	2·25
	18·375

The other bicitricate of ammonia is deposited at a low temperature. It crystallizes in long prisms, which effloresce rapidly when exposed to the air. The constituents are

2 atoms citricic acid . .	14
1 atom ammonia . . .	2·125
4 atoms water . . .	4·5
	20·625

2. *Citricate of potash.* This salt, when neutral, does not crystallize. When evaporated to dryness, it speedily deliquesces into a liquid, if it be left exposed to the atmosphere. It is insoluble in alcohol.

3. *Citricate of soda.* The neutral citricate deliquesces. The bicitricate of soda forms opaque fibrous crystals. It is very soluble in water.

4. *Citricate of barytes.* When obtained by evaporation, it is in crystalline crusts, which are more soluble in water than citricate of lime.

The bicitricate of barytes is also soluble, and more so in hot than cold water. It crystallizes in small rhomboidal tables, not altered by exposure to the air. Its constituents are

2 atoms citricic acid . .	14
1 atom barytes . . .	9·5
2 atoms water	2·25
	25·75

5. *Citricate of strontian.* The neutral salt dissolves in water, and forms, by evaporation, crystalline crusts in needles, interlaced together. The bicitricate is in crystalline plates, not altered by exposure to the air, and soluble in water.

6. *Citricate of lime.* When the aqueous solution of this salt is evaporated, the citricate is deposited in acicular prisms, interlaced with each other. At 64°, it dissolves in 45 times its weight of water. Boiling water does not dissolve any additional quantity. It is insoluble in alcohol. Its constituents are

1 atom citricic acid . . .	7
1 atom lime	3·5
1 atom water	1·125
	11·625

The bicitricate of lime forms crystalline plates, not altered by exposure to the air, and soluble at 50° in from 13 to 14 times its weight of water. Its constituents are

2 atoms citricic acid . .	14
1 atom lime	3·5
3 atoms water . . .	3·375
	20·875

7. *Citricate of magnesia.* The neutral salt does not crystallize. When evaporated to dryness it assumes the aspect of gum. The bicitricate of magnesia is very soluble and crystallizes in brilliant plates.

8. *Citricate of manganese* forms reddish crystalline crusts, soluble in water.

9. *Citricate of nickel*, a very pale bluish-green powder, very little soluble in water.

10. *Citricate of lead.* It is formed by double decomposition, when solutions of acetate of lead and bicitricate of ammonia are mixed together. It is a white powder, soluble in an excess of either of the two salts employed in its formation. Its constituents are

1 atom citricic acid . .	7
1 atom oxide of lead . .	14
1 atom water . . .	1·125
	22·125

11. *Citricate of copper.* Very small acicular crystals, having a greenish-blue colour, and very little soluble in water.

12. *Citricate of silver.* A white crystalline powder, composed of

1 atom citricic acid . . .	7
1 atom oxide of silver . .	14·5
	21·5

PARATARTARIC ACID.

Should have come in at page 63, *after tartaric acid.*

When tartaric acid is exposed to a moderate temperature, it loses water, and is converted into a liquid, which concretes on cooling. This constitutes a new acid, composed of 3 atoms tartaric acid, and 2 atoms water.

It forms with the bases a set of salts, differing in their constitution from the tartrates, being all compounds of 2 atoms of base with 3 atoms of tartaric acid. So that the water of the acid is replaced by a corresponding quantity of base.

These salts gradually undergo spontaneous decomposition, being resolved into free tartaric acid and tartrates.

A still more remarkable alteration takes place when tartaric acid is exposed to a higher temperature. It loses an additional dose of water, and we obtain an acid insoluble in water, which is a compound of 3 atoms tartaric acid and 1 atom of water. With the bases it forms neutral salts, containing 3 atoms tartaric acid and 1 atom of base.

We see here the striking analogy between tartaric and phosphoric acid.*

SABADILLINA (*page* 243).

M. Simon, of Berlin, assures us that the sabadillina of Couerbe is nothing else than a compound of resinate of soda and resinate of veratrina. If we dissolve it in water acidulated with sulphuric acid, and precipitate by an excess of ammonia, we obtain pure veratrina.†

DUMASIN (*page* 362).

This is a name given by Mr Kane to a new substance which he obtained in minute quantity, together with acetone, when acetate of lime was distilled at a high temperature. It is a liquid, which boils at 248°, and has

* Fremy, Ann. der Pharm. xix. 197. † See Poggendorf's Annalen, xliii. 403.

a resinoid character. According to the analysis of Mr Kane, which has been confirmed by Dumas, its constituents are

Carbon . .	78·82 or 10 atoms	= 7·5
Hydrogen .	10·46 or 8 atoms	= 1
Oxygen . .	10·72 or 1 atom	= 1
	100·00	9·5

It is therefore isomeric with camphor, though nothing can be more different than the properties of the two bodies. The specific gravity of its vapour is 5·204. Now

10 volumes carbon weigh .	4·1666
8 volumes hydrogen . .	0·5555
½ volume oxygen . . .	0·5555
	5·2777

We see from this that it is composed of 10 volumes carbon, 8 volumes hydrogen, and half a volume oxygen, condensed into 1 volume. This is the case also with the vapour of camphor, with which dumasin agrees in composition, though its properties are very different.

PECTIC ACID (*page* 146).

M. REGNAULT has subjected pectic acid to an analysis, and found it composed of

Carbon	42·71 or 11 atoms	= 8·25	or per cent.	43·14
Hydrogen	4·73 or 7 atoms	= 0·875	— —	4·57
Oxygen	52·56 or 10 atoms	= 10·00	— —	52·29
	100·00	19·125		100·00

M. Regnault endeavoured to determine the atomic weight of pectic acid, by mixing in various ways pectate of ammonia and nitrate of silver. But the salts formed were obviously mixtures. They consisted of 14·5 oxide of silver combined with 23·66; 24·61 and 21·40 of pectic acid. While pectate of lead was composed of 14 oxide + 14·6 pectic acid.*

ACETONE (*page* 362).

THE constituents of this substance, from the analysis of Liebig and Dumas, have been stated (page 364), to be $C^3 H^3 O$. Mr Kane, of Dublin, has made an interesting set of experiments on the compounds derived from this substance, which he considers as analogous to alcohol, and which he has called *mesitic alcohol*. He represents the constituents by the formula $C^6 H^6 O^2$, or double the preceding, so that its atomic weight is 7·25.

When acetone is mixed with sulphuric acid and distilled, a colourless liquid passes over, having an alliaceous smell, and boiling at 276°. It is composed of

6 atoms carbon	4·5
4 atoms hydrogen . . .	0·5
	5

Mr Kane has given the name of *mesytelen* to this liquid.

When perchloride of phosphorus is made to act on acetone, *phospho-*

* See Jour. de Pharmacie, xxiv. 201.

mesitylic acid is formed, together with a fluid heavier than water, and composed of C^6 H^5 Chl. Mr Kane considers this liquid as the chloride of a radical of mesitylen, to which he gives the name of *mesityle*. He has obtained

C^6 H^5 + O, or oxide of mesityl
C^6 H^5 + Chl, or chloride of mesityl
C^6 H^5 + Iod, or iodide of mesityl.

Oxide of mesityl unites with sulphuric acid in two proportions, forming the sulphate and bisulphate of mesityl. He calls the salts of the former acid, *sulphomesitylates*, and those of the latter, *persulphomesitylates*. The base of these salts is just capable of neutralizing the sulphuric acid which they contain. Thus, *sulphomesitylate* of lime is S O^3 + C^6 H^5 O + Cal O + H O.

When, in the process of making iodide of mesityl, an excess of phosphorus is used, there is obtained in the retort a white matter in silky crystals, which dissolves in water, is very acid, and forms well characterized salts. Mr Kane calls this acid *hypophosphomesitylous acid*, and states its composition to be Ph^2 O + C^6 H^5 O.

In decomposing acetone by perchloride of phosphorus, an acid is obtained, composed of Ph $O^{2\frac{1}{2}}$ + 2 (C^6 H^5 O).

When dry chlorine gas is passed into pure acetone, muriatic acid is given off, and white prismatic crystals formed composed of C^6 H^3 Chl.

A yellow substance obtained by the action of iodine, or nascent mesitylen, was considered by him as composed of C^6 H^3 Iod.

When mesitylene is treated with nitric acid, copious red fumes are given off, and a heavy thick fluid obtained, composed of C^6 H^4 O^2. This fluid absorbs ammonia and forms a compound soluble in water, and giving insoluble precipitates with most metallic solutions.

When acetone is heated with concentrated nitric acid, the action is violent and explosion takes place. The addition of water prevents this; but the resulting product cannot be analyzed.

To connect the above results Mr Kane assumes as a radical the body C^6 H^3, which he calls *pteleyl*.

C^6 H^3 + H, Hydret of pteleyl, or mesitylene
C^6 H^3 + Chl., Chloride of pteleyl
C^6 H^3 + Iod., Iodide of pteleyl
C^6 H^3 O + H O, Hydrated oxide of pteleyl, the aldehyde of the mesitic series
C^6 H^3 O + Az O^3, Hyponitrate of ptelyel.

The compound heavy liquid, produced by the action of chlorine on mesitic alcohol, was composed of C^6 H^3 O^2 Chl^2. By the action of bases it yields a metallic chloride and a salt of a new acid, called by Mr Kane *Pteleic acid*. He conjectures it to be C^6 H^3 O^4.

By the action of permanganate of potash on acetone, a salt is obtained containing an acid, to which Mr Kane has given the name of *perpteleic*. Its salts readily decompose themselves into carbonates, and a salt of another acid, which Mr Kane has called *acetonic*. These acids have not yet been sufficiently investigated.

The paper containing these interesting investigations was read to the Irish Academy on March 16, and April 10, 1837.

ORCEIN *(page* 404).

This substance has been analyzed by Dumas, who found it composed of

16 atoms carbon	. .	= 12
8 atoms hydrogen	. .	= 1
1 atom azote	. . .	= 1·75
6 atoms oxygen	. .	= 6
		20·75

It combines with 2 atoms of oxide of silver, and forms a diorceate of silver.

According to Dumas, orcin is composed of

18 atoms carbon	= 13·5	or per cent.	68·36
10 atoms hydrogen	= 1·25	— —	6·32
5 atoms oxygen	= 5·0	— —	25·32
	19·75		100·00

This is one atom of hydrogen less than by the analysis of Robiquet.

GALACTIN *(page* 448).

SINCE writing the account of galactin I have subjected it to an ultimate analysis, and obtained

Carbon	71·90 or 6 atoms = 4·5	or per cent.	72
Hydrogen	11·87 or 6 atoms = 0·75	— —	12
Oxygen	16·23 or 1 atom = 1	— —	16
	6·28		100

It is therefore isomeric with Brazil wax, as may be seen by comparing Oppermann's analysis of Brazil wax, given in page 447, with the above analysis. From Oppermann's short description of Brazil wax, I think it likely that it is the same substance as galactin. It is white, he says, has a specific gravity of 0·97, melts at 102°, and becomes solid at 97°. He says, indeed, that it combines with alkalies, and forms a soap which is soluble in water. Should this be confirmed by subsequent experiments it will constitute an important difference between the two. But Brandes says expressly that he could not combine Brazil wax with alkalies.

BEES' WAX *(page* 444).

IT is stated that *bees' wax* was, by John, separated into two distinct substances, *cerin* and *myricin*. But M. Hess has published a set of experiments to prove that bees' wax, when pure, is always of the same constitution and characters; but that, by oxidation, it is converted into an acid, which he calls *ceraïnsaune*, and to which we may give the name of *ceric* acid. The difference between cerin and myricin he considers as owing to the presence of more or less of this acid in the wax.

He took a quantity of yellow wax, and by means of ether deprived it of the colouring matter. The remaining white wax possessed the characters of the myricin of John. He found the constituents of wax to be

Carbon	79·77	giving 20 atoms = 15	or per cent.	81·0
Hydrogen	12·95	— 20 atoms = 2·5	— —	13·5
Oxygen	7·33	— 1 atom = 1·0	— —	5·4
	100·00	18·5		100·0

In ceric acid the carbon and hydrogen have the same ratio to each other as in wax; but the oxygen is increased. He considers it as a compound of

20 atoms carbon	= 15	or per cent.		73·17
20 atoms hydrogen	= 2·5	—	—	12·19
3 atoms oxygen	= 3	—	—	14·64
	20·5			100·00

It is not unlikely that M. Hess's explanation of the supposed difference between cerin and myricin is correct, but his formulas do not correspond so well with the result of his analysis as those of Ettling.*

VOLATILE OILS *(page* 452).

A PAPER, detailing the analysis of several volatile oils, by Mr Kane of Dublin, was read at a meeting of the Royal Irish Academy, June 12, 1837. I shall here state the results.

1. Oil of *mentha pulegium*, or *penny royal*. It boils, like oil of turpentine, at 314°, and is composed of C^{10} H^8.

2. Oil of *mentha sativa*. It boils at 320°, and is composed of C^{35} H^{28} O, or of $3\frac{1}{2}$ (C^{10} H^8) + O.

3. Oil of *origanum vulgare*, or *marjoram*. It boils at 324°, and is composed of C^{50} H^{40} O, or 5 (C^{10} H^8) + O.

4. Oil of *lavender*. It boils at 365°, and is composed of C^{12} H^{10} O.

5. Oil of *rosemary*. Its specific gravity is 0·85, and it boils at 332°. It is composed of C^{45} H^{38} O^2, or $4\frac{1}{2}$ (C^{10} H^8) + H^2 O^2.

6. Oil of *peppermint*. Pure English oil of peppermint has a specific gravity of 0·899, and boils at 365°, and is composed of C^{25} H^{22} O^2, or $2\frac{1}{2}$ (C^{10} H^8) + 2 (H O). This differs from the analysis of Blanchet and Sell, given in page 474 of this volume. But Mr Kane found that foreign oil of peppermint was always mixed with oil of turpentine.

OIL OF CLOVES *(page* 465).

DUMAS has made a new analysis of oil of cloves, to which he has given the name of *eugenic* acid, and considers it as composed of

20 atoms carbon . . .	= 15
12 atoms hydrogen . .	= 1·5
5 atoms oxygen . . .	= 5
	21·5

But he determined the specific gravity of the vapour of this acid oil, and found it 6·4. It is obvious from this that the true atomic weight of the acid cannot be far from 24. For 23·75 × 0·2777 = 6·6. Hence the constitution of the acid is probably

23 atoms carbon	= 17·25	or per cent.		71·87
14 atoms hydrogen	= 1·75	—	—	7·29
5 atoms oxygen	= 5	—	—	28·84
	24			100·00

which agrees well with the result obtained by M. Ettling, and given in page 468 of this volume.

EMULSIN *(page* 682).

M. SIMON, of Berlin, prepared emulsin from bitter almonds, sweet almonds, poppy seeds, hemp seeds, and black and white mustard, by the following process:—

* See Poggendorf's Annalen, xliii. 382.

One part of the seeds was made into an emulsion with eight parts of water. The emulsion being passed through a cloth, was mixed with a sufficient quantity of alcohol to coagulate the whole. The coagulum was separated by the filter, dried, reduced to powder, and digested with ether till that liquid ceased to dissolve any fat oil. It was then washed with alcohol, again dried and pulverized. The emulsin from all these seeds, when mixed with amygdalin, produced the smell of bitter almonds. That from bitter almonds acted most powerfully, that from sweet almonds next, that from hemp seed was weaker, and that from mustard weakest of all.*

TABLES,

SHOWING THE SPECIFIC GRAVITY OF THE VAPOUR OF VARIOUS VOLATILE BODIES, THAT OF AIR BEING RECKONED UNITY.

THERE is an intimate connexion between the specific gravity of the vapours of bodies and their atomic weight, as is manifest from the doctrine of volumes, so happily established by M. Gay-Lussac. This renders the knowledge of the specific gravity of vapours of importance. It often furnishes data for determining the atomic weight of bodies, which, not being capable of uniting with other substances in definite proportions, could not be ascertained by any other known method. I shall therefore, in the following tables, exhibit the specific gravity of the vapours hitherto determined. For these determinations we are chiefly indebted to the ingenious labours of M. Mitscherlich and M. Dumas.

The specific gravity of a vapour is always equal to its atomic weight, multiplied by a certain number, which is always a multiple or submultiple of the specific gravity of oxygen gas. The reason of this is, that oxygen is the substance whose atomic weight is represented by unity. The specific gravity of oxygen gas is $1{\cdot}111\dot{1}$, and the only submultiples or multiples of that specific gravity, which, multiplied into the atomic weight of a vapour, gives its specific gravity, are

$0{\cdot}277\dot{7}$ or $\frac{1}{4}$th of $1{\cdot}111\dot{1}$
$0{\cdot}555\dot{5}$ or $\frac{1}{2}$ of $1{\cdot}1111$
$1{\cdot}1111$
$2{\cdot}222\dot{2}$ or twice $1{\cdot}1111$
$3{\cdot}333\dot{3}$ or thrice $1{\cdot}1111$

* See Poggendorf's Annalen, xliii. 404.

TABLE I.

Specific gravity of vapour = atomic weight × 0·2777

Names of vapours.	Atomic weights.	Specific gravities.	
		By experiment.	By calculation.
Calomel	Hg^2 Chl = 29·5	8·35	8·194$\dot{4}$
Dibromide of mercury	Hg^2 Br = 35	10·11	9·722$\dot{2}$
Solid Chloride of phosphorus	Ph Chl^3 = 15·5	4·85	4·355$\dot{5}$
Alcohol	C^4 H^5 O + H O = 5·75	1·613	1·597$\dot{2}$
Aldehyde	C^4 H^3 O + H O = 5·5	1·532	1·527$\dot{7}$
Bromide of Aldehyden	C^4 H^3 Br = 13·375	3·691	3·71525
Iodide of Aldehyden	C^4 H^3 Iod = 19·125	4·76	5·3125
Chloroform	C^2 H Chl^3 = 15·125	4·199	4·201$\dot{5}$
Bromoform	C^2 H Br^3 = 31·625	8·7847	8·784$\dot{6}$
Chloral	C^4 H O^2 + Chl^3 = 18·625	5·13	5·1736$\dot{1}$
Oil of cloves, or eugenic acid	C^{22} H^{14} O^5 = 23·25	6·4	6·6
Benzoic acid	C^{14} H^5 O^3 = 14·125	4·27	3·923$\dot{6}$
Muriatic ether	C^4 H^5 O + H Chl = 9·25	2·289	2·569$\dot{4}$
Hydriodic ether	C^4 H^5 O + H Iod = 20·5	5·475	5·6944
Nitrous ether	C^4 H^5 O + Az O^3 = 9·375	2·626	2·604$\dot{1}$
Acetic ether	C^4 H^5 O + C^4 H^3 O^3 = 11	3·067	3·055$\dot{5}$
Benzoic ether	C^4 H^5 O + C^{14} H^5 O^3 = 18·75	5·409	5·208$\dot{3}$
Pyromucic ether	C^4 H^5 O + C^{10} H^3 O^5 = 17·5	4·859	4·861$\dot{1}$
Chlorocarbonic ether	C^4 H^5 O + C^2 H^3 Chl = 13·625	3·82	3·78361
Mercaptan	C^4 H^5 S + H S = 7·78	2·326	2·152$\dot{7}$
Nitrobenzide	C^{12} H^5 Az O^4 = 15·375	4·40	3·7152$\dot{7}$
Urethan	C^6 H^7 Az O^4 = 10·875	3·096	3·0208$\dot{3}$

Names of vapours.	Atomic weights.	Specific gravities.	
		By experiment.	By calculation.
Pyroxylic spirit	$C^2 H^3 O + H O = 4$	1·12	1·111i
Muriate of Methylene	$C^2 H^3 O + H Chl = 7·5$	1·731	2·083i
Hydriodate of methylene	$C^2 H^3 O + H Iod = 18·75$	4·883	5·208i
Fluate of methylene	$C^2 H^3 O + H Fl = 5·25$	1·186	1·458i
Nitrate of methylene	$C^2 H^3 O + Az O^5 = 9·625$	2·653	2·6736i
Acetate of methylene	$C^2 H^3 O + C^4 H^3 O^3 = 9·25$	2·563	2·569i
Formate of methylene	$C^2 H^3 O + C^2 H O^3 = 7·5$	2·084	2·083i
Benzoate of methylene	$C^2 H^3 O + C^{14} H^5 O^3 = 17$	4·717	4·722i

TABLE II.

Specific gravity of vapours = atomic weight × 0·5555

Names of vapours.	Atomic weights.	Specific gravities.	
		By experiment.	By calculation.
Chlorine	Chl = 4·5	2·5	2·5
Bromine	Br = 10		5·555
Iodine	Iod = 15·75	8·75?	8·75
Mercury	Hd = 12·5	7·03	6·944i
Corrosive sublimate	Hd Chl = 17	9·80	9·444i
Bromide of mercury	Hd Br = 22·5	12·16	12·5
Iodide of mercury	Hd Iod = 28·25	16·20	15·6944
Sulphuric acid	$S O^3 = 5$	3·00	2·777i
Selenious acid	$Sl O^2 = 7$	4·03	3·888i

Names of vapour.	Atomic weights.	Specific gravities.	
		By experiment.	By calculation.
Acetic acid	$C^4\ H^3\ O^3 = 6{\cdot}375$	2·77	3·5416
Sesquichloride of antimony	$St\ Chl^{1\frac{1}{2}} = 14{\cdot}75$	7·80	8·1944
Alkarsin	$C^4\ H^6\ Strs^2 = 13{\cdot}25$	7·184	7·361
Ether	$C^4\ H^5\ O = 4{\cdot}625$	2·586	2·5694
Carbonic ether	$C^4\ H^5\ O + C\ O^2 = 7{\cdot}125$	4·243	3·9583
Oxalic ether	$C^4\ H^5\ O + C^2\ O^3 = 9{\cdot}125$	5·087	5·0694
Succinic ether	$C^4\ H^5\ O + C^4\ H^2\ O^3 = 10{\cdot}875$	6·22	6·0416
Œnanthic ether	$C^4\ H^5\ O + C^{14}\ H^{13}\ O^2 = 18{\cdot}75$	10·508	10·4166
Sulphate of methylene	$C^2\ H^3\ O + S\ O^3 = 7{\cdot}875$	4·565	4·375
Methylic ether	$C^2\ H^3\ O = 2{\cdot}875$	1·617	1·5972
Chloride of deuto-hydrogen	$C^2\ H^2\ Chl = 6{\cdot}75$	3·45	3·6388
Bromide of deuto-hydrogen	$C^2\ H^2\ Br = 11{\cdot}75$	6·483	6·5277
Benzin	$C^6\ H^3 = 4{\cdot}875$	2·77	2·7083
Camphor	$C^{10}\ H^8\ O = 9{\cdot}5$	5·468	5·2777
Dumasin	$C^{10}\ H^8\ O = 9{\cdot}5$	5·204	5·2777
Acetone	$C^3\ H^3\ O = 3{\cdot}625$	2·019	2·0138
Ethal	$C^{16}\ H^{17}\ O = 15{\cdot}125$	7·846	8·4027
Oil of turpentine	$C^{10}\ H^8 = 8{\cdot}5$	4·765	4·7222
Oil of potatoes	$C^5\ H^6\ O = 5{\cdot}5$	3·147	3·0555
Cetene	$C^{16}\ H^{16} = 14$	8·007	7·7777
Elain	$C^9\ H^9 = 7{\cdot}875$	4·075	4·375
Olein	$C^6\ H^6 = 5{\cdot}25$	2·875	2·9166
Naphthalin	$C^{10}\ H^4 = 8$	4·528	4·4444
Paranaphthalin	$1\frac{1}{2}\ (C^{10}\ H^4) = 12$	6·741	6·6666
Retinaphtha	$C^7\ H^4 = 5{\cdot}75$	3·23	3·2444
Orcin	$C^{18}\ H^{10}\ O^5 = 19{\cdot}75$	5·7	6·094

TABLE III.

Specific gravity = atomic weight × 1·111$\dot{1}$

Name of vapour.	Atomic weight.	Specific gravity.	
		By experiment.	By calculation.
Oxygen . . .	O = 1	1·111$\dot{1}$	1·111$\dot{1}$

TABLE IV.

Specific gravity = atomic weight × 2·222$\dot{2}$

Names of vapours.	Atomic weights.	Specific gravities.	
		By experiment.	By calculation.
Phosphorus . . .	Ph = 2	4·465	4·444$\dot{4}$
Arsenic . . .	Ars = 4·75	10·65	10·555$\dot{5}$
Arsenious acid . .	Ars $O^{1\frac{1}{2}}$ = 6·25	13·85	13·888$\dot{8}$

TABLE V.

Specific gravity = atomic weight × 3·333$\dot{3}$

Name of vapour.	Atomic weight.	Specific gravity.	
		By experiment.	By calculation.
Sulphur . . .	S = 2	6·658	6·666$\dot{6}$

The two following substances, if the specific gravity of their vapours has been rightly determined by Mitscherlich, do not come under any of the preceding divisions:—

Names of vapours.	Atomic weights.	Specific gravities.
Cinnabar . .	Hd S = 14·5	5·95
Iodide of arsenic .	Ars Iod = 20·5	16·10

The first of these approaches 14·5 × 0·416$\dot{6}$, or $\frac{3}{8}$ths of the specific gravity of oxygen gas; the second to 20·5 × 0·833$\dot{3}$, or $\frac{5}{6}$ds the specific gravity of oxygen gas. For 14·5 × 0·416$\dot{6}$ = 6·041$\dot{6}$, and 20·5 × 0·833$\dot{3}$ = 17·073$\dot{3}$. But the temperature of these vapours was so high that accurate results could not be expected.

It is obvious that the atomic weight of the substances in the first table is obtained by dividing the specific gravity of the vapour by 0·277$\dot{7}$. The same result is obtained with those in the second table by dividing the specific gravity of the vapour by 0·555$\dot{5}$, in the third table by 1·1111, in the fourth table by 2·222$\dot{2}$, and in the fifth table by 3·333$\dot{3}$.

If we consider the atoms entering into the constitution of the bodies in table 1st as volumes, it is obvious that the whole of them are condensed in the vapours so as to constitute two volumes; while those in table 2d constitute only one volume, those in table 3d half a volume, those in table 4th $\frac{1}{4}$th of a volume, and those in table 5th $\frac{1}{6}$th of a volume. In other words, a volume of the bodies in table 3d is equivalent to two atoms, a volume in table 4th to four atoms, and a volume in table 5th to six atoms.

TABLE

Exhibiting the Composition and Atomic Weights of the Bodies described in this volume, Oxygen being unity.

	Composition.	Atomic weight.
Deutocarbohydrogen .	C^2H^2	1·75
Methyl . . .	C^2H^3	1·875
Idrialin . . .	C^3H	2·375
Methylene . . .	C^2H^3O	2·875
Pyroxylic alcohol . .	C^2H^3+HO	3
Cyanogen . . .	C^2Az	3·25
Hydrocyanic acid . .	C^2AzH	3·375
Aldehyden . . .	C^4H^3	3·375
Light oil of wine . .	C^4H^4	3·5
Caoutchouc . . .	C^4H^4	3·5
Acetone . . .	C^3H^3O	3·625
Pyroxylic spirit . .	C^2H^3O+HO	4
Cyanic acid . . .	C^2AzO	4·28
Oxide of aldehyden .	C^4H^3O	4·375
Oil of iris florentina .	C^4H^4O	4·5
Oxalic acid . . .	C^2O^3	4·5
Ether	C^4H^5O	4·625
Formic acid . . .	C^2HO^3	4·625
Oil of ethyl . . .	C^4H^5O	4·625
Benzin	C^6H^3	4·875
Aldehyde resin . .	C^5H^3O	5·125
Fluoride of methylene .	C^2H^3O+HFl	5·25?
Olein of Fremy . .	C^6H^6	5·25
Salicin	$C^4H^3O^2$	5·375
Cyanuric acid (insoluble)	$\frac{1}{2}(C^2Az)+H^3O^3$	5·375?
Aldehyde . . .	C^4H^3O+HO	5·5
Oil of potatoes . .	C^5H^6O	5·5
Oxamide . . .	$C^2O^2+AzH^2$	5·5
Alcohol . . .	C^4H^5O+HO	5·75
Oil of parsley . .	$C^6H^{3\frac{1}{2}}O$	5·9375
Equisetic acid . .	C^4HO^3	6·125
Maleic acid . . .	C^4HO^3	6·125
Metacetone . . .	C^6H^5O	6·125
Brazil wax . . .	C^6H^6O	6·25
Galactin . . .	C^6H^6O	6·25
Succinic acid . . .	$C^4H^2O^3$	6·25
Chloride of deutohydrogen	C^2H^2+Chl	6·25
Acetic acid . . .	$C^4H^3O^3$	6·375
Aldehydic acid . .	$C^4H^3O^2+HO$	6·5
Chloride of cyanogen .	$C^2Az+Chl$	6·75
Camphor from oil of parsley	$C^{10}H^3O^2$	6·875
Cyanodide of ethyl . .	$C^4H^5+C^2Az$	6·875

	Composition.	Atomic weight.
Hydrocarbo sulphuric acid	S^2C+SH	6·875
Paramaleic acid . .	$C^5H^2O^3$	7
Pyrocitric acid . .	$C^5H^2O^2$	7
Citricic acid . . .	$C^5H^2O^3$	7
Fumaric acid . . .	$C^5H^2O^3$	7
Olivilin	$C^6H^{4\frac{1}{2}}O^2$	7·0625
Carbonic ether . .	$C^4H^5O+CO^2$	7·125
Mellitic acid . . .	C^4HO^4	7·125
Pyrotartaric acid . .	$C^5H^3O^3$	7·125
Citric acid . . .	$C^4H^2O^4$	7·25
Malic acid . . .	$C^4H^2O^4$	7·25
Succinamide . . .	$C^4H^2O^2+AzH^2$	7·25
Sulphuret of cyanogen .	C^2Az+S^2	7·25
Chloride of benzin . .	$C^6H^{1\frac{1}{2}}Chl^{1\frac{1}{2}}$	7·3175
Hydrosulphocyanic acid .	$(C^2Az+H)+S^2$	7·375
Volatile oil of asarum .	C^8H^4O?	7·5?
Chloride of methylene .	$C^2H^3O+HChl$	7·5
Formate of methylene .	$C^2H^3O+C^2HO^3$	7·5
Urea	$C^2H^4Az^2O^2$	7·5
Ammonia-aldehyde .	$C^4H^4O^2+AzH^3$	7·625
Croconic acid . .	C^5O^4	7·75
Mercaptan . . .	C^4H^5S+HS	7·75
Chloride of aldehyden .	C^4H^3+Chl	7·875
Sulphate of methylene .	$C^2H^3O+SO^3$	7·875
Elain of Fremy . .	C^9H^9	7·875
Naphthalin . . .	$C^{10}H^4$	8
Cyanuric acid . .	$1\frac{1}{2}(C^2Az)+H^{1\frac{1}{2}}O^3$	8·0625
Chloride of ethyl . .	C^4H^5+Chl	8·125
Racemic acid . . .	$C^4H^2O^5$	8·25
Tartaric acid . . .	$C^4H^2O^5$	8·25
Oil of styrax . . .	$C^{10}H^7$	8·375
Eupion	$C^{9\frac{1}{2}}H^{10}$	8·375
Oil of lemons . . .	$C^{10}H^8$	8·5
Oil of copaiva . .	$C^{10}H^8$	8·5
Oil of pepper . . .	$C^{10}H^8$	8·5
Oil of juniper berries .	$C^{10}H^8$	8·5
Oil of savine . . .	$C^{10}H^8$	8·5
Oil of turpentine . .	$C^{10}H^8$	8·5
Citrene	$C^{10}H^8$	8·5
Pyrogallic acid . .	$C^6H^3O^3$	8·875
Lactic acid . . .	$C^6H^4O^4$	9
Chloroxalic acid . .	C^2O^3Chl	9
Elemi resin . . .	$C^{10}H^8O^{\frac{1}{2}}$	9
Oxalic ether . . .	$C^4H^5O+C^2O^3$	9·125
Acetate of methylene .	$C^2H^3O+C^4H^3O^3$	9·25
Formic ether . . .	$C^4H^5O+C^2HO^3$	9·25
Camphor from oil of anise	$C^{10}H^6O$	9·25
Oil of fennel . . .	$C^{10}H^6O$	9·25
Oil of anise . . .	$C^{10}H^6O$	9·25
Oxalhydric acid . .	$C^4H^3O^6$	9·375
Nitric ether . . .	$C^4H^5O+AzO^3$	9·375

	Composition.	Atomic weight.
Urethylan	$C^4H^5AzO^4$	9·375
Camphor	$C^{10}H^8O$	9·5
Dumasin	$C^{10}H^8O$	9·5
Ellagic acid	$C^7H^2O^4$	9·5
Xanthic oxide	$C^5H^2Az^2O^2$	9·5
Nitrate of methylene	$C^2H^3O+AzO^5$	9·625
Resinon	$C^{10}H^9O$	9·625
Butyric acid	$C^8H^5O^3$	9·625
Oil of cajeput	$C^{10}H^9O$	9·625
Suberic acid	$C^7H^6O^3$	9·75
Camphor from oil of lavender	$C^{10}H^{10}O$	9·75
Allantoin	$C^4Az^2+H^3O^3$	9·875
Pyruvic acid	$C^6H^3O^5$	9·875
Cahincic acid	$C^{7\frac{1}{2}}H^6O^{3\frac{1}{2}}$	9·875
Creosote	$C^6H^{3\frac{1}{2}}O$	9·9375
Acetal	$C^8H^9O^3$	10·125
Caffeic acid	$C^5H^4O^6$	10·25
Glycerin	$C^6H^7O^5$	10·375
Cyanamide	$C^4H^4Az^4$	10·5
Pasto resin	$C^{10}H^8O^2$	10·5
Chlorocyanate of methylene	$C^2H^3O+C^2AzChl$	10·625
Gallic acid	$C^7H^3O^5$	10·625
Persian naphtha	$C^{12}H^{12}$	10·625
Parillina	$C^9H^8O^3$	10·75
Stiracin	$C^{11}H^5O^2$	10·875
Succinic ether	$C^4H^5O+C^4H^2O^3$	10·875
Urethan	$C^6H^7AzO^4$	10·875
Acetic ether	$C^4H^5O+C^4H^3O^3$	11
Quassite	$C^{10}H^6O^3$	11·25
Oil of lavender	$C^{12}H^{10}O$	11·25
Benzone	$C^{13}H^5O$	11·375
Camphoric acid	$C^{10}H^7O^3$	11·375
Phocenic acid	$C^{10}H^{7\frac{1}{2}}O^3$	11·4375
Melon	C^6Az^4	11·5
Nitrosulphuric acid	$2(AzO^2)+SO^2$	11·5
Sebacic acid	$C^{10}H^8O^3$	11·5
Bicoloric acid	$C^8H^{4\frac{1}{2}}O^5$	11·5625
Valerianic acid	$C^{10}H^9O^3$	11·625
Hydromelonic acid	C^6Az^4H	11·625
Naphthalic acid	$C^{10}H^2O^4$	11·75
Bromide of deutohydrogen	C^2H^2+Br	11·75
Paranaphthalin	$1\frac{1}{2}(C^{10}H^4)$	11·75
Pyrotartaric ether	$C^4H^5O+C^5H^3O^3$	11·75
Citric ether	$C^4H^5O+C^4H^2O^4$	11·875
Malic ether	$C^4H^5O+C^4H^2O^4$	11·875
Oxychloro-carbonate of methylene	$C^2H^3O+C^2ClO^3$	11·875
Mucic acid	$C^6H^4O^7$	12
Paramucic acid	$C^6H^4O^7$	12
Naphthalase	$C^{14}H^{4\frac{1}{2}}O$?	12·0625

	Composition.	Atomic weight.
Meconin . . .	$C^{10}H^5O^4$	12·125
Chlorocyanic ether . .	$C^4H^5O+C^2AzChl$	12·375
Metagallic acid . .	$C^{12}H^3O^3$	12·375
Chloric ether . .	$C^4H^4Chl^2$	12·5
Meconic acid . . .	$C^7H^2O^7$	12·5
Bisulphate of methylene .	$C^2H^3O+^2(SO^3)$	12·875
Oxamethane . . .	$C^6H^5AzO^6$?	12·875?
Pyromucic acid . .	$C^{10}H^3O^5$	12·875
Pyromeconic acid . .	$C^{10}H^3O^5$	12·875
Tartaric ether . .	$C^4H^5O+C^4H^2O^5$	12·875
Viscin	$C^{15}H^{10}O^2$?	13
Benzoyl . . .	$C^{14}H^5O^2$	13·125
Benzoin . . .	$C^{14}H^5O^2+H$	13·25
Caproic acid . . .	$C^{12}H^{10}O^3$	13·25
Volatile oil of bitter almonds	$C^{14}H^6O^2$	13·25
Bromide of aldehyden .	C^4H^3Br	13·375
Conicina . . .	$C^{12}H^{14}AzO$	13·5
Crenic acid . . .		13·5
Japonic acid . . .	$C^{12}H^4O^4$	13·5
Phosphovinic acid . .	$2(PhO^{2\frac{1}{2}})+C^4H^5O$	13·625
Spiroil	$C^{12}H^5O^4$	13·625
Bromide of ethyl . .	C^4H^5Br	13·625
Chlorocarbonic ether .	$C^4H^5O+C^2O^3Chl$	13·625
Chloroxalic ether . .	$C^4H^5O+C^2O^3Chl$	13·625
Resin of Euphorbium .	$C^{15}H^{12}O$	13·75
Hydrospiroilic acid .	$C^{12}H^6O^4$	13·75
Cetene	$C^{16}H^{16}$	14
Sulphomethylic acid .	$2(SO^3)+C^2H^3O+HO$	14
Œnanthic acid . .	$C^{14}H^{13}O^2$	14·125
Aspartic acid . .	$C^8H^5AzO^6$	14·375
Suberic ether . .	$C^4H^5O+C^8H^6O^3$	14·375
Sulphobenzide . .	$C^{12}H^5+SO^3$	14·625
Ethionic acid . . .	$S^2O^5+C^4H^4O+HO$	14·625
Melam . . .	$C^6H^{4\frac{1}{2}}Az^{5\frac{1}{2}}$	14·6875
Camphor from oil of cubebs	$C^{16}H^{14}O$	14·75
Cyanate of methylene .	$C^2H^3O+2(C^2AzO)+3(HO)$	14·75
Oxalovinic acid . .	$2(C^2O^3)+C^4H^5O+HO$	14·75
Mucate of methylene .	$C^2H^3O+C^6H^4O^7$	14·875
Picrotoxic acid . .	$C^{12}H^7O^5$	14·875
Cystic oxide . .	$C^6H^6AzO^8$	15
Hyponitromeconic acid .	$\frac{1}{2}(AzO^4)+C^{10}H^5O^4$	15
Benzamide . . .	$C^{14}H^5O^2+AzH^2$	15·125
Chloroform . . .	C^2H+Chl^3	15·125
Ethal . . .	$C^{16}H^{17}O$	15·125
Xanthic acid . . .	$2(S^2C)+C^4H^5O+HO$	15·25
Indigogen . . .	$C^{16}H^5AzO$	15·375
Asparamide . .	$C^8H^5AzO^5+AzH^2$	15·375
Nitrobenzide . . .	$C^{12}H^5AzO^4$	15·375
Althionic acid . .	$2(SO^3)+C^4H^5O+HO$	15·75
Melamin . . .	$C^6H^6Az^6$	15·75
Amelin	$C^6H^5Az^5O^2$	15·878

	Composition.	Atomic weight.
Solid chloride of naphthalin	$C^{10}H^{3}Chl^{2}$	15·878
Amelide . . .	$C^{6}H^{4\frac{1}{2}}Az^{4\frac{1}{2}}O^{3}$	15·9378
Santalin . . .	$C^{16}H^{8}O^{3}$	16
Sulphomethylane . .	$(C^{2}H^{3}+SO^{3})+(AzH^{3})+SO^{2}$	16
Sulphuret of benzoil .	$C^{14}H^{5}O^{3}+S$	16·125
Cyanilic acid . . .	$3(C^{2}HAzO^{2})$	16·125
Apocrenic acid . .		16·5
Indigotic acid . .	$C^{16}H^{6}AzO^{2}$	16·5
Cyanic ether . . .	$C^{4}H^{5}O+2(C^{2}AzO)+3(HO)$	16·5
Mucic ether . . .	$C^{4}H^{5}O+C^{6}H^{4}O^{7}$	16·625
Oil of cinnamon . .	$C^{18}H^{9}O^{2}+H$	16·75
Cerin	$C^{18}H^{18}O$	16·75
China nova bitter . .	$C^{15}H^{12}O^{4}$	16·75
Cerain	$C^{18}H^{18}O$	16·75
Myracin . . .	$C^{18}H^{18}O$	16·75
Catechuic acid . .	$C^{15}H^{5}O^{5}$	16·875
Benzoate of methylene .	$C^{2}H^{3}O+C^{14}H^{5}O^{3}$	17
Petrolene . . .	$C^{20}H^{16}$	17
Camphene . . .	$C^{20}H^{16}$	17
Cinnamonic acid . .	$C^{18}H^{7}O^{3}$	17·375
Azulmic acid . .	$C^{8}H^{4}Az^{4}O^{4}$	17·5
Pyromucic ether . .	$C^{4}H^{5}O+C^{10}H^{3}O^{5}$	17·5
Iodide of deutohydrogen	$C^{2}H^{2}+Iod$	17·5
Chloride of benzoyl .	$C^{14}H^{5}O^{2}+Chl$	17·625
Spiroilic acid . .	$C^{12}H^{5}O^{4}+O^{4}$	17·625
Cholesteric acid . .	$C^{13}H^{10}Az^{\frac{1}{2}}O^{6}$	17·875
Resinein . . .	$C^{20}H^{15}O$	17·875
Anchusic acid . .	$C^{17}H^{10}O^{4}$	18
Capric acid . . .	$C^{18}H^{14}O^{3}$	18·25
Chloral . . .	$C^{4}HO^{2}+Chl^{3}$	18·628
Amidin	$C^{10}H^{10}O^{10}$	18·75
Benzoic ether . .	$C^{4}H^{5}O+C^{14}H^{5}O^{3}$	18·75
Iodide of methylene .	$C^{2}H^{3}O+HIod$	18·75
Menespermina . .	$C^{18}H^{12}AzO^{2}$	18·75
Œnanthic ether . .	$C^{4}H^{5}O+C^{14}H^{13}O^{2}$	18·75
Roccellic acid . .	$C^{17}H^{16}O^{4}$	18·75
Hyposulphonapthalic acid	$(SO^{3})+C^{11}H^{4\frac{1}{2}}$	18·8125
Lichenin . . .	$C^{10}H^{11}O^{10}$	18·875
Caryophillin . . .	$C^{20}H^{16}O^{2}$	19
Capaiva resin . .	$2(C^{10}H^{8}O)$?	19?
Pectic acid . .	$C^{11}H^{7}O^{10}$	19·125
Iodide of aldehyden .	$C^{4}H^{3}+Iod$	19·125
Iodide of ethyl . .	$C^{4}H^{5}+Iod$	19·375
Sulphoglyceric . .	$S^{2}O^{5}+C^{6}H^{7}O^{5}$	19·375
Tartromethylic acid .	$2(C^{4}H^{2}O^{5})+C^{2}H^{3}O$	19·375
Metameconic acid . .	$C^{12}H^{4}O^{10}$	19·5
Succinone . . .	$C^{21}H^{10}O^{2}$	19·75
Cinchonina . . .	$C^{20}H^{12}AzO^{1\frac{1}{2}}$	19·75
Orcin	$C^{18}H^{10}O^{5}$	19·75
Bassorin . . .	$C^{10}H^{11}O^{11}$	19·875
Bromide of cyanogen .	$1\frac{1}{2}(C^{2}Az)+Br^{1\frac{1}{2}}$	19·875

	Composition.	Atomic weight.
Asphaltene	$C^{20}H^{16}O^{3}$	20
Amylin	$C^{12}H^{10}O^{10}$	20·25
Hordein	$C^{12}H^{10}O^{10}$	20·28
Quinina	$C^{20}H^{12}AzO^{2}$	20·25
Common sugar	$C^{12}H^{10}O^{10}$	20·28
Sugar of milk	$C^{12}H^{10}O^{10}$	20·25
Chloronaphthalase	$C^{20}H^{7}Chl$	20·375
Chlorophenesic acid	$C^{12}H^{3}O^{2}Chl^{2}$	20·375
Racemomethylic acid	$2(C^{4}H^{2}O^{5})+C^{2}H^{3}O+HO$	20·5
Resineon	$C^{23}H^{18}O$?	20·5
Phloridzin	$C^{14}H^{9}O^{9}$	20·625
Pollenin of cedar	$C^{11}H^{20}O^{10}$	20·75
Orcein	$C^{16}H^{8}AzO^{6}$	20·75
Eblanin	$C^{21}H^{9}O^{4}$	20·875
Uric acid	$C^{10}H^{4}Az^{4}O^{6}$	21
Arecina	$C^{20}H^{12}AzO^{2}$	21·25
Hippuric acid	$C^{18}H^{8}AzO^{5}$	21·25
Arabin	$C^{12}H^{11}O^{11}$	21·375
Cerasin	$C^{12}H^{11}O^{11}$	21·375
Kinic acid	$C^{15}H^{9}O^{9}$	21·375
Mechloic acid	$C^{14}H^{7}O^{10}$	21·375
Oxalate of melamine	$C^{6}H^{6}Az^{6}+C^{2}O^{3}+HO$	21·375
Nitronaphthalase	$C^{29}H^{7}+AzO^{4}$?	21·625
Resin of gamboge	$C^{20}H^{14}O^{5}$	21·75
Racemovinic acid	$2(C^{4}H^{2}O^{5})+C^{4}H^{5}O+HO$	22·25
Tartrovinic acid	$2(C^{4}H^{2}O^{5})+C^{4}H^{5}O+HO$	22·25
Lignin	$C^{15}H^{10}O^{10}$	22·5
Sugar of grapes	$C^{12}H^{12}O^{12}$	22·5
Nitrate of melamin	$C^{6}H^{6}Az^{6}+AzO^{5}$	22·5
Oil of mustard	$S^{2\frac{1}{2}}C^{10}H^{10}AzO^{2\frac{1}{2}}$	22·5
Mannite	$C^{12}H^{14}O$	22·75
Atropina	$C^{22}H^{15}AzO^{3}$	23·125
Bromide of benzoin	$C^{14}H^{5}O^{2}+Br$	23·125
Oil of roses	$C^{23}H^{23}O^{3}$	23·125
Sabadillina	$C^{20}H^{13}AzO^{5}$	23·375
Benzosulphuric acid	$S^{2}O^{5}+C^{16}H^{4}O^{2}$?	23·5?
Bromic ether	$C^{4}H^{4}+Br^{2}$	23·5
Crystals from oil of turpentine	$C^{20}H^{20}O^{6}$	23·5
Oil of peppermint	$2\frac{1}{2}(C^{10}H^{8})+2(HO)$	23·5
Bromide of spiroil	$C^{12}H^{5}O^{4}+Br$	23·625
Hydrosulphuret of cyanogen	$3(C^{2}Az)+6(HS)+HO$	23·625
Nitrate of ammelin	$C^{6}H^{5}Az^{5}O^{2}+AzO^{5}$	23·75
Arseniovinic acid	$2(ArsO^{2\frac{1}{2}})+2(C^{4}H^{5}O)$?	23·75?
Oil of cloves, or eugenic acid	$C^{23}H^{14}O^{5}$	24
Volatile oil of mustard	$S^{2\frac{1}{2}}C^{16}H^{10}Az^{2}O^{2\frac{1}{2}}$	24·25
Chloronaphthalese	$C^{20}H^{6}Chl^{2}$	24·75
Chlorophenisic acid	$C^{12}H^{3}O^{2}Chl^{3}$	24·875
Sulphonaphthalic acid	$S^{2}O^{3}+C^{20}H^{7}$	24·875
Pollenin of lycopodium	$C^{17}H^{17\frac{1}{2}}O^{10}$	24·9375
Ricinic acid	$C^{24}H^{24}O^{4}$	25

	Composition.	Atomic weight.
Thebaina . . .	$C^{25}H^{14}AzO^{3}$	25·25
Bromonaphthalese . .	$C^{2}H^{7}+Br$	25·875
Benzosulphate of methylene	$C^{2}H^{3}O+(S^{2}O^{5}+C^{16}H^{4}O^{2})$	26·378
Tannic acid . . .	$C^{18}H^{8}O^{12}$	26·5
Delphina . . .	$C^{27}H^{18}AzO^{2}$	26·75
Nitronaphthalese . .	$C^{20}H^{6}+Az^{2}O^{8}$	27·25
Benzimide . . .	$C^{28}H^{11}AzO^{4}$	28·125
Amide of oil of mustard	$S^{2}C^{16}H^{10}Az^{2}O^{2}+Az^{2}H^{4}$	28·25
Camphovinic acid . .	$2(C^{10}H^{7}O^{3})+C^{4}H^{5}O+HO$	28·5
Iodide of benzoil . .	$C^{14}H^{5}O^{2}+Iod$	28·875
Iodide of spiroil . .	$C^{12}H^{5}O^{4}+Iod$	29·375
Oil of mentha sativa .	$3\frac{1}{2}(C^{10}H^{8})$	29·75
Ambrein . . .	$C^{33\frac{1}{2}}H^{32}O$	30·125
Strychnina . . .	$C^{30}H^{16}AzO^{4}$	30·25
Margarone . . .	$C^{34}H^{32}O$	30·5
Carbazotic acid . .	$C^{15}Az^{3}O^{15}$	31·5
Bromoform . . .	$C^{2}H+Br^{3}$	31·625
Wax of ceroxylon andicola	$C^{35}H^{29}O^{2}$	31·875
Muriate of cetene . .	$2(C^{16}H^{16})+HChl$	32·625
Staphisin . . .	$C^{32}H^{24}AzO^{4}$	32·75
Codeina . . .	$C^{32}H^{19}AzO^{5}$	33·125
Coal naphtha . .	$C^{39}H^{24}O$	33·25
Elaidic acid . . .	$C^{35}H^{33}O^{3}$	33·375
Bees' wax . . .	$C^{37}H^{39}O^{2}$	34·625
Brucina . . .	$C^{32}H^{18}AzO^{7}$	35
Iodic ether . . .	$C^{4}H^{4}Iod^{2}$	35
Bromal . . .	$C^{4}HO^{2}+Br^{3}$	35·125
Morphina . . .	$C^{34}H^{18}AzO^{6}$	35·5
Veratrina . . .	$C^{34}H^{22}AzO^{6}$	36
Emetina . . .	$C^{35}H^{25}AzO^{5}$	36·125
Emulsin . . .	$C^{24}H^{23}Az^{4}O^{9}$	36·875
Oil of rosemary . .	$4\frac{1}{2}(C^{10}H^{8})+2(HO)$	38·25
Narceina . . .	$C^{28}H^{20}AzO^{12}$	37·25
Pinic acid . . .	$4(C^{10}H^{7\frac{1}{2}}O)$	37·75
Elaidic ether . . .	$C^{4}H^{5}O+C^{35}H^{33}O^{3}$	38
Silvic acid . . .	$4(C^{10}H^{8}O)$	38
Copaiva acid . . .	$C^{40}H^{32}O^{4}$	38
Saponin . . .	$C^{26}H^{23}O^{16}$	38·375
Alizarin . . .	$C^{37}H^{12}O^{10}$	39·25
Ulmic acid . . .	$C^{30}H^{15}O^{15}$	39·375
Berberite . . .	$C^{33}H^{18}AzO^{12}$	40
Oil of marjoram . .	$5(C^{10}H^{8})+O$	43·5
Narcotina . . .	$C^{40}H^{20}AzO^{12}$	46·25
Iodoform . . .	$C^{2}H+Iod^{3}$	48·875
Insoluble chloral . .	$C^{12}H^{4}O^{7}+Chl^{8}$	52·5
Gentisic acid . .		54·73?
Amygdalin . . .	$C^{40}H^{26}AzO^{22}$	57
Amygdalic acid . .	$C^{40}H^{26}O^{24}$	57·25
Oleon	$C^{68}H^{60}O$	59·5
Stearone . . .	$C^{68}H^{67}O$	60·375
Sulphocetic acid . .	$S^{2}O^{5}+C^{64}H^{32}+2(HO)$	63·25

	Composition.	Atomic weight.
Stearic acid	$C^{70}H^{67}O^{5}$	65·875
Metamargaric acid	$C^{70}H^{67}O^{6}$	66·875
Oleic acid	$C^{70}H^{62}O^{7}$	67·25
Santonic acid	$C^{60}H^{36}O^{12}$	67·5
Esculic acid	$C^{52}H^{46}O^{24}$	68·75
Metoleic acid	$C^{70}H^{64}O^{9}$	69·5
Margaric acid	$C^{70}H^{70}O^{9}$	70·28
Hydroleic acid	$C^{70}H^{65}O^{10}$	70·625
Hydromargaric acid	$C^{70}H^{71}O^{10}$	71·375
Olein	$2(C^{35}H^{30}O^{2\frac{1}{2}})+C^{6}H^{7}O^{5}+2(HO)$	77·625
Aurade	$C^{97}H^{105}O$	86·875
Stearin	$C^{140}H^{134}O^{10}+C^{6}H^{7}O^{5}+2(HO)$	144·375
Spermaceti	$\left\{\begin{array}{l}2(C^{70}H^{64}O^{6})+2(C^{70}H^{60}O^{5})+\\ 3(C^{16}H^{16})+3(HO)\end{array}\right\}$	308·375

THE PRECEDING ATOMIC WEIGHTS ARRANGED ALPHABETICALLY.

	Composition.	Atomic weight.
A		
Acetal	$C^{8}H^{9}O^{3}$	10·125
Acetate of methylene	$C^{2}H^{3}O+C^{4}H^{3}O^{3}$	9·25
Acetic acid	$C^{4}H^{3}O^{3}$	6·375
Acetic ether	$C^{4}H^{5}O+C^{4}H^{3}O^{3}$	11
Acetone	$C^{3}H^{3}O$	3·625
Alcohol	$C^{4}H^{5}O+HO$	5·75
Aldehyde	$C^{4}H^{3}O+HO$	5·5
Aldehyde resin	$C^{5}H^{3}O$	5·125
Aldehyden	$C^{4}H^{3}$	3·875
Aldehydic acid	$C^{4}H^{4}O^{2}+O$	6·5
Alizarin	$C^{37}H^{12}O^{10}$	39·25
Allantoin	$C^{4}Az^{2}+H^{3}O^{3}$	9·875
Althionic acid	$2(SO^{3})+C^{4}H^{5}O+HO$	15·75
Ambreic acid	$C^{57}H^{47}Az^{4}O^{27}$	82·625
Ambrein	$C^{33\frac{1}{2}}H^{32}O$	30·125
Amide of oil of mustard	$S^{2}\}C^{16}H^{10}Az^{2}O^{2\frac{1}{2}}+Az^{2}H^{4}\}$	28·875
Amidin	$C^{10}H^{10}O^{10}$	18·75
Ammelin	$C^{6}H^{5}Az^{5}O^{2}$	15·875
Ammelide	$C^{6}H^{4\frac{1}{2}}Az^{4\frac{1}{2}}O^{3}$	15·9375
Ammonialdehyde	$C^{4}H^{4}O^{2}+AzH^{3}$	7·625
Amygdalin	$C^{40}H^{26}AzO^{22}$	57
Amygdalic acid	$C^{40}H^{26}O^{24}$	57·25
Amylin	$C^{12}H^{10}O^{10}$	20·28
Anchusic acid	$C^{17}H^{10}O^{4}$	18
Apocrenic acid		16·5
Arabin	$C^{12}H^{11}O^{16}$	21·375

	Composition.	Atomic weight.
Arecina . . .	$C^{20}H^{12}AzO^3$	21·25
Arseniovinic acid . .	$2(AsO^{2\frac{1}{2}})+2(C^4H^5O)$	23·75
Asarum, oil of . .	C^8H^4O?	7·5?
Asparamide . . .	$C^8H^5AzO^5+AzH^2$	15·375
Aspartic acid . . .	$C^8H^5AzO^6$	14·375
Asphaltene . . .	$C^{20}H^{16}O^3$	20
Atropina . . .	$C^{22}H^{15}AzO^3$	23·125
Aurade	$C^{97}H^{105}O$	86·875
Azulmic acid . . .	$C^8H^4Az^4O^4$	17·5
B		
Bassorin . . .	$C^{10}H^{11}O^{11}$	19·875
Benzamide . . .	$C^4H^5O^2+AzH^2$	15·128
Benzimide . . .	$C^{28}H^{11}AzO^4$	20·125
Benzin	C^6H^3	4·878
Benzoate of methylene .	$C^2H^3O+C^{14}H^5O^3$	17
Benzoic acid . . .	$C^{14}H^5O^3$	14·125
Benzoic ether . .	$C^4H^5O+C^{14}H^5O^3$	18·75
Benzoin . . .	$C^{14}H^5O^2+H$	13·25
Benzone . . .	$C^{13}H^5O$	11·375
Benzosulphuric acid .	$S^2O^5+C^{16}H^4O^2$?	23·5
Benzoyl . . .	$C^{14}H^5O^2$	13·125
Berberite . . .	$C^{33}H^{18}AzO^{12}$	40
Bicoloric acid . .	$C^8H^{4\frac{1}{2}}O^5$	11·5625
Benzosulphate of methylene	$C^2H^3O+(Sl^2O^5+C^{16}H^4O^2)$	26·375
Bisulphate of methylene .	$C^2H^3O+2(SlO^2)$	12·875
Brazil wax . . .	C^6H^6O	6·25
Bromal	$C^4HO^2+Br^3$	35·125
Bromic ether . . .	$C^4H^4+Br^2$	23·5
Bromide of aldehyden .	C^4H^3+Br	13·375
Bromide of benzoin .	$C^{14}H^5O^2+Br$	23·125
Bromide of cyanogen .	$1\frac{1}{2}(C^2Az)+Br^{1\frac{1}{2}}$	19·875
Bromide of deutohydrogen	C^2H^2+Br	11·75
Bromide of ethyl . .	C^4H^5Br	13·625
Bromide of spiroil . .	$C^{12}H^5O^4Br$	23·625
Bromoform . . .	C^2H+Br^3	31·625
Bromonaphthalase . .	$C^{20}H^7+Br$	25·875
Brucina . . .	$C^{32}H^{18}AzO^7$	35
Butyric acid . . .	$C^8H^5O^3$	9·625
C		
Caffeic acid . . .	$C^5H^4O^6$	10·25
Caffein	$C^4H^{2\frac{1}{2}}AzO$	6·0625
Cahincic acid . .	$C^{7\frac{1}{2}}H^6O^{3\frac{1}{2}}$	9·875
Cajeput, oil of . .	$C^{10}H^9O$	9·628
Camphene . . .	$C^{20}H^{16}$	17
Camphor . . .	$C^{10}H^8O$	9·8
Camphor from oil of anise	$C^{10}H^6O$	9·25
Camphor from oil of cubebs	$C^{16}H^{14}O$	14·75
Camphor from oil of lavender . .	$C^{10}H^{10}O$?	9·75?

	Composition.	Atomic weight.
Camphor from oil of parsley	$C^{10}H^{3}O^{2}$	6·875
Camphoric acid . .	$C^{10}H^{7}O^{3}$	11·375
Camphovinic acid . .	$2(C^{10}H^{7}O^{3})+C^{4}H^{5}O+HO$	28·5
Caoutchene . . .	$C^{x}H^{x}$	0·875^{x}
Caoutchouc . . .	$C^{4}H^{4}$	3·5
Capric acid . . .	$C^{18}H^{14}O^{3}$	18·28
Caproic acid . . .	$C^{12}H^{10}O^{3}$	13·25
Carbazotic acid . .	$C^{15}Az^{3}O^{15}$	31·5
Carbonic ether . .	$C^{4}H^{5}O+CO^{2}$	7·128
Caryophillin . . .	$C^{20}H^{16}O^{2}$	19
Catechuic acid . .	$C^{15}H^{5}O^{5}$	16·875
Cerain	$C^{18}H^{18}O$	16·75
Cerasin	$C^{12}H^{11}O^{11}$	21·375
Cerin	$C^{18}H^{18}O$	16·75
Cetene	$C^{16}H^{16}$	14
China nova bitter . .	$C^{15}H^{12}O^{4}$	16·75
Chloral	$C^{4}HO^{2}+Chl^{3}$	18·625
Chloric ether . .	$C^{4}H^{4}+Chl^{2}$	12·5
Chloride of aldehyden .	$C^{4}H^{3}+Chl$	7·875
Chloride of benzin . .	$C^{6}H^{\frac{1}{2}}Chl^{\frac{1}{2}}$	7·3175
Chloride of benzoyl .	$C^{14}H^{5}O^{2}+Chl$	17·625
Chloride of cyanogen .	$C^{2}Az+Chl$	6·75
Chloride of deutohydrogen	$C^{2}H^{2}+Chl$	6·28
Chloride of ethyl . .	$C^{4}H^{5}+Chl$	8·125
Chloride of methylene .	$C^{2}H^{3}O+HChl$	7·5
Chloride of spiroil . .	$C^{12}H^{5}O^{4}+Chl$	18·128
Chlorocarbonic ether .	$C^{4}H^{5}O+C^{2}O^{3}Chl$	13·628
Chlorocyanate of methylene	$C^{2}H^{3}O+C^{2}AzChl$	10·625
Chlorocyanic ether .	$C^{4}H^{5}O+C^{2}AzChl$	12·375
Chloroform . . .	$C^{2}H+Chl^{3}$	15·128
Chloronaphthalase . .	$C^{20}H^{7}Chl$	20·375
Chloronaphthalese . .	$C^{20}H^{6}Chl^{2}$	24·78
Chlorophenesic acid .	$C^{12}H^{3}O^{2}Chl^{2}$	20·375
Chlorophenisic acid .	$C^{12}H^{3}O^{2}Chl^{3}$	24·875
Chloroxalic acid . .	$C^{2}O^{3}+Chl$	9
Chloroxalic ether . .	$C^{4}H^{5}O+C^{2}O^{3}Chl$	13·628
Cholesteric acid . .	$C^{13}H^{10}Az^{\frac{1}{2}}O^{6}$	17·875
Cinchonina . . .	$C^{20}H^{12}AzO^{1\frac{1}{2}}$	19·75
Cinnamon, oil of . .	$C^{18}H^{9}O^{2}+H$	16·75
Cinnamonic acid . .	$C^{18}H^{7}O^{3}$	17·375
Citrene	$C^{10}H^{8}$	8·5
Citric acid . . .	$C^{4}H^{2}O^{4}$	7·25
Citric ether . . .	$C^{4}H^{5}O+C^{4}H^{2}O^{4}$	11·875
Citricic acid . . .	$C^{5}H^{2}O^{3}$	7
Cloves, oil of . . .	$C^{23}H^{14}O^{5}$	24
Codeina . . .	$C^{32}H^{19}AzO^{5}$	33·125
Columbin . . .	$C^{12}H^{7}O^{4}$	13·875
Conicina . . .	$C^{12}H^{14}AzO$	13·5
Copaiva acid . . .	$C^{40}H^{32}O^{4}$	38
Copaiva, volatile oil from	$C^{10}H^{8}$	8·5
Copaiva resin . .	$2(C^{10}H^{8}O)$?	19?

	Composition.	Atomic weight.
Coumarin	$C^{10}H^3O^2$	9·875
Crenic acid		13·5
Creosote	$C^6H^{3\frac{1}{2}}O$	9·9375
Croconic acid	C^5O^4	7·75
Cyanamide	$\{C^4H^4Az^4$ or $2(C^2AzO)+2(H^3Az)-2(HO)\}$	10·5
Cyanate of methylene	$C^2H^3O+2(C^2AzO)+3(HO)$	14·75
Cyanide of benzoyle	$C^{14}H^5O^2+C^2Az$	16·375
Cyanic acid	C^2Az+O	4·25
Cyanic ether	$C^4H^5O+2(C^2AzO)+3(HO)$	16·5
Cyanilic acid	$3(C^2HAzO^2)$	16·128
Cyanodide of ethyl	$C^4H^5+C^2Az$	6·875
Cyanogen	C^2Az	3·28
Cyanuric acid	$1\frac{1}{2}(C^2Az)+H^{1\frac{1}{2}}O^3$	8·0625
Cyanuric acid, insoluble	$\frac{1}{2}(C^2Az)H^{1\frac{1}{2}}O^3$	8·8625
Cystic oxide	$C^6H^6AzO^8$	15
D		
Delphina	$C^{27}H^{18}AzO^{2\frac{1}{2}}$	26·75
Deutohydrogen	C^2H^2	1·75
Dumasin	$C^{10}H^8O$	9·5
E		
Eblanin	$C^{21}H^9O^4$	20·875
Elaidic acid	$C^{35}H^{33}O^3$	33·375
Elaidic ether	$C^4H^5O+C^{35}H^{33}O^3$	38
Elain of Fremy	C^9H^9	7·875
Elemi resin	$C^{10}H^8O^{\frac{1}{2}}$	9
Ellagic acid	$C^7H^2O^4$	9·5
Emetina	$C^{35}H^{25}AzO^9$	40·125
Emulsin	$C^{26}H^{23}Az^4O^9$	36·875
Enanthic ether	$C^4H^5O+C^{14}H^{13}O^2$	18·75
Equisetic acid	C^4HO^3	6·125
Esculic acid	$C^{52}H^{46}O^{24}$	68·75
Ethal	$C^{16}H^{17}O$	15·125
Ether	C^4H^5O	4·625
Ethionic acid	$Sl^2O^5+C^4H^4O+HO$	14·625
Eugenic acid	$C^{23}H^{14}O^5$	24
Eupion	$C^{9\frac{1}{2}}H^{10}$	8·375
F		
Fennel, oil of	$C^{10}H^6O$	9·25
Fluoride of methylene	C^2H^3O+HFl	5·25?
Formate of methylene	$C^2H^3O+C^2HO^3$	7·5
Formic acid	C^2HO^3	4·625
Formic ether	$C^4H^5O+C^2HO^3$	9·25
Fumaric acid	$C^5H^2O^3$	7
G		
Galactin	$C^6H^6O^1$	6·25
Gallic acid	$C^7H^3O^5$	10·625

	Composition.	Atomic weight.
Gentisic acid		54·73?
Glycerin	$C^6H^7O^5$	10·375
H		
Hevein	C^xH^x	0·875^x
Hordein	$C^{12}H^{10}O^{10}$	20·25
Hippuric acid	$C^{18}H^8AzO^5$	21·25
Hydrocarbosulphuric acid	S^2C+SH	6·875
Hydrocyanic acid	C^2Az+H	3·375
Hydroleic acid	$C^{70}H^{65}O^{10}$	70·625
Hydromargaric acid	$C^{70}H^{71}O^{10}$	71·375
Hydromelonic acid	C^6Az^4+H	11·625
Hydrospiroilic acid	$C^{12}H^6O^4$	13·75
Hydrosulphuret of cyanogen	$3(C^2Az)+H^6S^6+HO$	23·628
Hydrosulphocyanic acid	$(C^2Az+H)+S^2$	7·375
Hyponitromeconic acid	$\frac{1}{2}(AzO^4)+C^{10}H^5O^4$	15
Hyposulphonaphthalic acid	$2(SO^3)+C^{11}H^{4\frac{1}{2}}$	18·8125
I		
Japonic acid	$C^{12}H^4O^4$	13·5
Idrialin	C^3H?	2·375?
Indigo	$C^{16}H^5AzO^2$	18·375
Indigogen	$C^{16}H^5AzO$ or $C^{16}H^6AzO^2$	15·378 / 16·5
Indigotic acid	$C^{23}H^{7\frac{1}{2}}Az^{1\frac{1}{2}}O^{15}$	
Insoluble chloral	$C^{12}H^4O^7+Chl^8$	52·5
Iodic ether	$C^4H^4+Iod^2$	35
Iodide of aldehyden	C^4H^3+Iod	19·128
Iodide of benzoyl	$C^{14}H^5O^2+Iod$	28·628
Iodide of deutohydrogen	C^2H^2+Iod	17·5
Iodide of ethyl	C^4H^5+Iod	19·375
Iodide of methylene	$C^2H^3O+HIod$	18·75
Iodide of spiroil	$C^{12}H^5O^4+Iod$	29·375
Iodoform	C^2H+Iod^3	48·875
Iris florentina, oil of	C^4H^4O	4·5
K		
Kinic acid	$C^{15}H^9O^9$	21·375
L		
Lactic acid	$C^6H^4O^4$	9
Lavender, oil of	$C^{12}H^{10}O$	11·25
Lavender, camphor from oil of	$C^{10}H^{10}O$	9·75
Lemons, oil of	$C^{10}H^8$	8·5
Lichenin	$C^{10}H^{11}O^{10}$	18·875
Lignin	$C^{15}H^{10}O^{10}$	22·5
M		
Maleic acid	C^4HO^3	6·125

	Composition.	Atomic weight.
Malic acid	$C^4H^2O^4$	7·25
Malic ether	$C^4H^5O+C^4H^2O^4$	11·875
Mannite	$C^{12}H^{14}O^{12}$	22·75
Margaric acid	$C^{70}H^{70}O^9$	70·25
Margarone	$C^{34}H^{32}O$	30·5
Marjoram, oil of	$5(C^{10}H^8+O)$	43·5
Mechloic acid	$C^{14}H^7O^{10}$	21·375
Meconic acid	$C^7H^2O^7$	12·5
Meconin	$C^{10}H^5O^4$	12·128
Melam	$C^6H^{4\frac{1}{2}}Az^{5\frac{1}{2}}$	14·6875
Melamine	$C^6H^6Az^6$	15·75
Mellitic acid	C^4HO^4	7·125
Melon	C^6Az^4	11·5
Menispermina	$C^{18}H^{12}AzO^2$	18·75
Mentha pulegium, oil of	$C^{10}H^8$	8·5
Mentha sativa, oil of	$3\frac{1}{2}(C^{10}H^8)$	29·75
Mercaptan	C^4H^5S+HS	7·75
Metacetone	C^6H^5O	6·125
Metagallic acid	$C^{12}H^3O^3$	12·375
Metamargaric acid	$C^{70}H^{67}O^6$	66·875
Metameconic acid	$C^{12}H^4O^{10}$	19·5
Methyl	C^2H^3	1·878
Methylene	C^2H^3O	2·878
Methylic ether	C^2H^3O	2·875
Metoleic acid	$C^{70}H^{64}O^9$	69·5
Morphina	$C^{34}H^{18}AzO^6$	35·5
Mucate of methylene	$C^2H^3O+C^6H^4O^7$	14·875
Mucic acid	$C^6H^4O^7$	12
Mucic ether	$C^4H^5+C^6H^4O^7$	16·628
Muriate of cetene	$2(C^{16}H^{16})+HChl$	32·625
Muriate of methylene	$C^2H^3O+HChl$	7·5
Mustard, volatile oil of, amide of	$S^{2\frac{1}{2}}C^{16}H^{10}Az^2O^{2\frac{1}{2}}+H^4Az^2$	28·25
Mustard, volatile oil of	$S^{2\frac{1}{2}}C^{16}H^{10}Az^2O^{2\frac{1}{2}}$	24·25
Myracin	$C^{18}H^{18}O$	16·78
N.		
Naphtha, coal	$C^{39}H^{24}O$	33·25
Naphthalase	$C^{14}H^{4\frac{1}{2}}O$	12·065?
Naphthalic acid	$C^{10}H^2O^4$	11·75
Naphthalin	$C^{10}H^4$	8
Narceina	$C^{28}H^{20}AzO^{12}$	37·25
Narcotina	$C^{40}H^{20}AzO^{12}$	46·28
Nitrate of ammelin	$C^6H^5Az^5O^2+AzO^5+HO$	23·75
Nitrate of melamin	$C^6H^6Az^6+AzO^5$	22·8
Nitrate of methylene	$C^2H^3O+AzO^5$	9·628
Nitric ether	$C^4H^5O+AzO^3$	9·375
Nitrobenzide	$C^{12}H^5AzO^4$	15·375
Nitronaphthalase	$C^{20}H^7+AzO^4$	21·625?
Nitronaphthalese	$C^{20}H^6+Az^2O^8$	27·25
Nitrosulphuric acid	$2(AzO^2)+SO^2$	11·5

	Composition.	Atomic weight.
O.		
Œnanthic acid	$C^{14}H^{13}O^2$	14·125
Œnanthic ether	$C^4H^5O+C^{14}H^{13}O^2$	18·75
Oil of anise	$C^{10}H^6O$	9·25
Oil of asarum	C^8H^4O	7·5
Oil of bitter almonds	$C^{14}H^5O^2+H$	13·25
Oil of cajeput	$C^{10}H^9O$	9·625
Oil of cinnamon	$C^{18}H^9O^2+H$	16·75
Oil of cloves	$C^{23}H^{14}O^5$	24
Oil of fennel	$C^{10}H^6O$	9·25
Oil of iris florentina	C^4H^4O	4·8
Oil of lavender	$C^{12}H^{10}O$	11·25
Oil of lemons	$C^{10}H^8$	8·8
Oil of marjoram	$5(C^{10}H^8)+O$	43·5
Oil of mentha sativa	$3\frac{1}{2}(C^{10}H^8)$	29·75
Oil of mustard	$S^{2\frac{1}{2}}C^{16}H^{10}AzO^{2\frac{1}{2}}$	22·5
Oil of parsley	$C^6H^{3\frac{1}{2}}O$	5·9375
Oil of pennyroyal	$C^{10}H^8$	8·5
Oil of pepper	$C^{10}H^8$	8·8
Oil of peppermint	$2\frac{1}{2}(C^{10}H^8)+2(HO)$	23·5
Oil of potatoes	C^5H^6O	5·8
Oil of rosemary	$4\frac{1}{2}(C^{10}H^8)+2(HO)$	38·25
Oil of roses	$C^{23}H^{23}O^3$	23·125
Oil of sabine	$C^{10}H^8$	8·5
Oil of turpentine	$C^{10}H^8$	8·5
Oily chloride of naphthalin	$C^{10}H^4Chl$	12·5
Oleic acid	$C^{70}H^{62}O^7$	67·25
Olein of Fremy	C^6H^6	5·25
Olein	$2(C^{35}H^{30}O^{2\frac{1}{2}})+C^6H^7O^5+2(HO)$	77·625
Oleon	$C^{68}H^{60}O$	59·5?
Olivilin	$C^6H^{4\frac{1}{2}}O^2$	7·0625
Orcein	$C^{16}H^8AzO^6$	20·75
Orcin	$C^{18}H^{10}O^5$	19·75
Oxalate of melamine	$C^6H^6Az^6+C^2O^3+HO$	21·375
Oxalhydric acid	$C^4H^3O^6$	9·375
Oxalic acid	C^2O^3	4·5
Oxalic ether	$C^4H^5O+C^2O^3$	9·125
Oxalovinic acid	$2(C^2O^3)+C^4H^5O+HO$	14·75
Oxamethane	$C^6H^5AzO^6$?	12·875?
Oxamide	$C^2O^2+AzH^2$	5·5
Oxide of aldehydene	C^4H^3O	4·378
Oxide of ethyl	C^4H^5O	4·628
Oxychlorocarbonate of methylene	$C^2H^3O+C^2ChlO^3$	11·875
P		
Paraffin	C^xH^x	$0·875^x$
Paramaleic acid	$C^5H^2O^3$	7
Paramucic acid	$C^6H^4O^7$	12
Paranaphthalin	$1\frac{1}{2}(C^{10}H^4)$	11·75
Parillina	$C^9H^8O^3$	10·75

	Composition.	Atomic weight.
Parsley, oil of	$C^6H^{3\frac{1}{2}}O$	5·9378
Parsley, oil of, camphor from	$C^6H^3O^2$	6·875
Pasto resin	$C^{10}H^8O^2$	10·5
Pectic acid	$C^{11}H^7O^{10}$	19·125
Pennyroyal, oil of	$C^{10}H^8$	8·5
Pepper, oil of	$C^{10}H^8$	8·5
Peppermint, oil of	$2\frac{1}{2}(C^{10}H^8)+2(HO)$	23·5
Persian naphtha	$C^{12}H^{12}$	10·5
Petrolene	$C^{20}H^{16}$	17
Phloridzin	$C^{14}H^9O^9$	20·628
Phocenic acid	$C^{10}H^{7\frac{1}{2}}O^3$	11·4378
Phosphovinic acid	$2(PhO^{2\frac{1}{2}})+C^4H^5O$	13·628
Picrotoxic acid	$C^{12}H^7O^5$	14·878
Pinic acid	$4(C^{10}H^{7\frac{1}{2}}O)$	37·75
Piperin	$C^{40}H^{20}AzO^6$	40·25
Pollenin of cedar	$C^{11}H^{20}O^{10}$	20·78
Pollenin of lycopodium	$C^{17}H^{17\frac{1}{2}}O^{10}$	24·9375
Potatoes, oil of	C^5H^6O	5·8
Pseuderythrin	$C^8H^5O^4$	10·628
Pyrocitric acid	$C^5H^2O^3$	7
Pyrocitric ether	$C^4H^5O+C^5H^2O^3$	11·628
Pyrogallic acid	$C^6H^3O^3$	8·875
Pyromeconic acid	$C^{10}H^3O^4$	12·875
Pyromucic acid	$C^{10}H^3O^5$	12·875
Pyromucic ether	$C^4H^5O+C^{10}H^3O^5$	17·5
Pyrotartaric acid	$C^5H^3O^3$	7·125
Pyrotartaric ether	$C^4H^5O+C^5H^3O^3$	11·78
Pyroxylic alcohol	C^2H^3+HO	3
Pyroxylic spirit	C^2H^3O+HO	4
Pyruvic acid	$C^6H^3O^5$	9·875
Q		
Quassite	$C^{10}H^6O^3$	11·25
Quinina	$C^{20}H^{12}AzO^2$	20·25
R		
Racemic acid	$C^4H^2O^5$	8·25
Racemomethylic acid	$2(C^4H^2O^5)+C^2H^3O+HO$	20·5
Racemovinic acid	$2(C^4H^2O^5)+C^4H^5O+HO$	22·25
Resin of euphorbium	$C^{15}H^{12}O$	13·75
Resin of gamboge	$C^{20}H^{14}O^5$	21·75
Resinein	$C^{20}H^{15}O$	17·875
Resineon	$C^{23}H^{18}O$?	20·5
Resinon	$C^{10}H^9O$	9·625
Ricinic acid	$C^{24}H^{24}O^4$	25
Roccellic acid	$C^{17}H^{16}O^4$	18·75
Rosemary, oil of	$4\frac{1}{2}(C^{10}H^8)$	38·25
Rubinic acid	$C^{18}H^6O^9$	23·25
S		
Sabadillina	$C^{20}H^{13}AzO^5$	23·375

	Composition.	Atomic weight.
Sabine, oil of	$C^{10}H^{8}$	8·5
Salicin	$C^{4}H^{3}O^{2}$	5·375
Santalin	$C^{16}H^{8}O^{3}$	16
Santonic acid	$C^{60}H^{36}O^{12}$	67·5
Saponin	$C^{26}H^{23}O^{16}$	28·378
Sarcocollin	$C^{22}H^{19}O^{10}$	28·878
Sebacic acid	$C^{10}H^{8}O^{3}$	11·5
Silvic acid	$4(C^{10}H^{8}O)$	3·8
Smilacic acid	$C^{8}H^{7\frac{1}{2}}O^{3}$	9·375
Solanina	$C^{56}H^{42}AzO^{7}$	56
Solid chloride of naphthalin	$C^{10}H^{3}Chl^{2}$	15·875
Spermaceti	$\left\{ \begin{matrix} 2(C^{70}H^{64}O^{6})+2(C^{70}H^{60}O^{5})+ \\ 3(C^{16}H^{16})+3(HO) \end{matrix} \right\}$	308·375
Spiroil	$C^{12}H^{5}O^{4}$	13·625
Spiroilic acid	$C^{12}H^{5}O^{4}+O^{4}$	17·625
Staphisin	$C^{32}H^{24}AzO^{4}$	32·75
Stearic acid	$C^{70}H^{6}O^{5}$	65·875
Stearin	$C^{140}H^{134}O^{10}+C^{6}H^{7}O^{5}+2(HO)$	144·375
Stearone	$C^{68}H^{67}O$	60·375
Stiracin	$C^{11}H^{5}O^{2}$	10·875
Strychnina	$C^{30}H^{16}AzO^{4}$	30·25
Suberic acid	$C^{8}H^{6}O^{3}$	9·75
Suberic ether	$C^{4}H^{5}O+C^{8}H^{6}O^{3}$	14·375
Succinamide	$C^{4}H^{2}O^{2}+AzH^{2}$	7·25
Succinic acid	$C^{4}H^{2}O^{3}$	6·25
Succinic ether	$C^{4}H^{5}O+C^{4}H^{2}O^{3}$	10·875
Succinone	$C^{21}H^{10}O^{2}$	19·75
Sugar, common	$C^{12}H^{10}O^{10}$	20·28
Sugar of grapes	$C^{12}H^{12}O^{12}$	22·8
Sugar of milk	$C^{12}H^{10}O^{10}$	20·28
Sulphate of methylene	$C^{2}H^{3}O+SO^{3}$	7·875
Sulphobenzide	$C^{12}H^{5}+SO^{3}$?	14·628
Sulphocetic acid	$S^{2}O^{5}+C^{64}H^{32}+2(HO)$	63·28
Sulphoglyceric acid	$S^{2}O^{5}+C^{6}H^{7}O^{5}$	19·378
Sulphohydric ether	$C^{4}H^{5}+HSl$?	
Sulphomethylene	$(C^{2}H^{3}+SO^{3})+(AzH^{3})+SO^{2}$	16
Sulphomethylic acid	$2(SO^{3})+C^{2}H^{3}O+HO$	14
Sulphonaphthalic acid	$S^{2}O^{5}+C^{20}H^{7}$	24·878
Sulphuret of benzoyl	$C^{14}H^{5}O^{3}+S$	6·125
Sulphuret of cyanogen	$C^{2}Az+S^{2}$	7·25
T		
Tannic acid	$C^{18}H^{8}O^{12}$	26·5
Tannin	$C^{18}H^{8}O^{12}$	26·5
Tartaric acid	$C^{4}H^{2}O^{5}$	8·28
Tartaric ether	$C^{4}H^{5}O+C^{4}H^{2}O^{5}$	12·875
Tartromethylic acid	$2(C^{4}H^{2}O^{5})+C^{2}H^{3}O$	19·378
Tartrovinic acid	$2(C^{4}H^{2}O^{5})+C^{4}H^{5}O$	22·28
Thebaina	$C^{25}H^{14}AzO^{3}$	25·25
Turpentine, oil of	$C^{10}H^{8}$	8·8
Turpentine, crystals from	$C^{20}H^{20}O^{6}$	23·5

	Composition.	Atomic weight.
U V		
Valerianic acid	$C^{10}H^9O^3$	11·628
Veratrina	$C^{34}H^{22}AzO^6$	36
Viscin	$C^{13}H^{10}O^2$?	13?
Ulmic acid	$C^{30}H^{15}O^{15}$	39·375
Volatile oil of anise	$C^{10}H^6O$	9·25
Volatile oil of asarum	C^8H^4O	7·5
Volatile oil of bitter almonds	$C^{14}H^6O^2$	13·25
Volatile oil of cajeput	$C^{10}H^9O$	9·625
Volatile oil of cinnamon	$C^{18}H^9O^2+H$	16·75
Volatile oil of cloves	$C^{23}H^{14}O^5$	24
Volatile oil of copaiva	$C^{10}H^8$	8·5
Volatile oil of fennel	$C^{10}H^6O$	9·28
Volatile oil of iris florentina	C^4H^4O	4·5
Volatile oil of juniper berries	$C^{10}H^8$	8·5
Volatile oil of lemons	$C^{10}H^8$	8·8
Volatile oil of mustard	$S^2\{C^{16}H^{10}Az^2O^2\}$	24·28
Volatile oil of parsley	$C^6H^{3\frac{1}{2}}O$	5·9375
Volatile oil of pepper	$C^{10}H^8$	8·8
Volatile oil of peppermint	$C^{12}H^5O$	10·628
Volatile oil of potatoes	C^5H^6O	5·5
Volatile oil of roses	$C^{23}H^{23}O^3$	23·128
Volatile oil of sabine	$C^{10}H^8$	8·5
Volatile oil of styrax	$C^{10}H^7$	8·375
Urea	$C^2H^4Az^2O^2$ or C^2AzO+H^3Az+HO	7·5
Urethan	$C^6H^7AzO^4$ or $(C^4H^5O+CO^2)+(CO+H^2Az)$	10·875
Urethylan	$C^4H^5AzO^4$?	9·375
Uric acid	$C^{10}Az^4H^4O^6$	21
W		
Wax, bees'	$C^{37}H^{39}O^2$	34·628
Wax of ceroxylon andicola	$C^{35}H^{29}O^2$	31·875
Wine, light oil of	C^4H^4	3·5
X		
Xanthic acid	$2(Sl^2C)+C^4H^5O+HO$	15·25
Xanthic oxide	$C^5H^2Az^2O^2$ or $C^{10}H^4Az^4O^4$	9·5 or 19

In these tables, I have not inserted the atomic weights according to the hydrogen scale, because they are very seldom used; but any person may easily convert the oxygen scale into the hydrogen, by multiplying the numbers in the table by 8. Thus, the atom of uric acid, according to the oxygen scale, is 21; according to the hydrogen scale, it is $21 \times 8 = 168$.

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