The elements of experimental chemistry (Volume 2).

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Thomas & Andrews
National Library of Medicine (U.S.)

Publication/Creation

Boston : Published by Thomas & Andrews ; sold by them and by Cummings & Hilliard ; also by Howe & Deforest, New-Haven, Nov. 1814 ([Boston] : Joseph T. Buckingham, printer)

Persistent URL

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ELEMENTS

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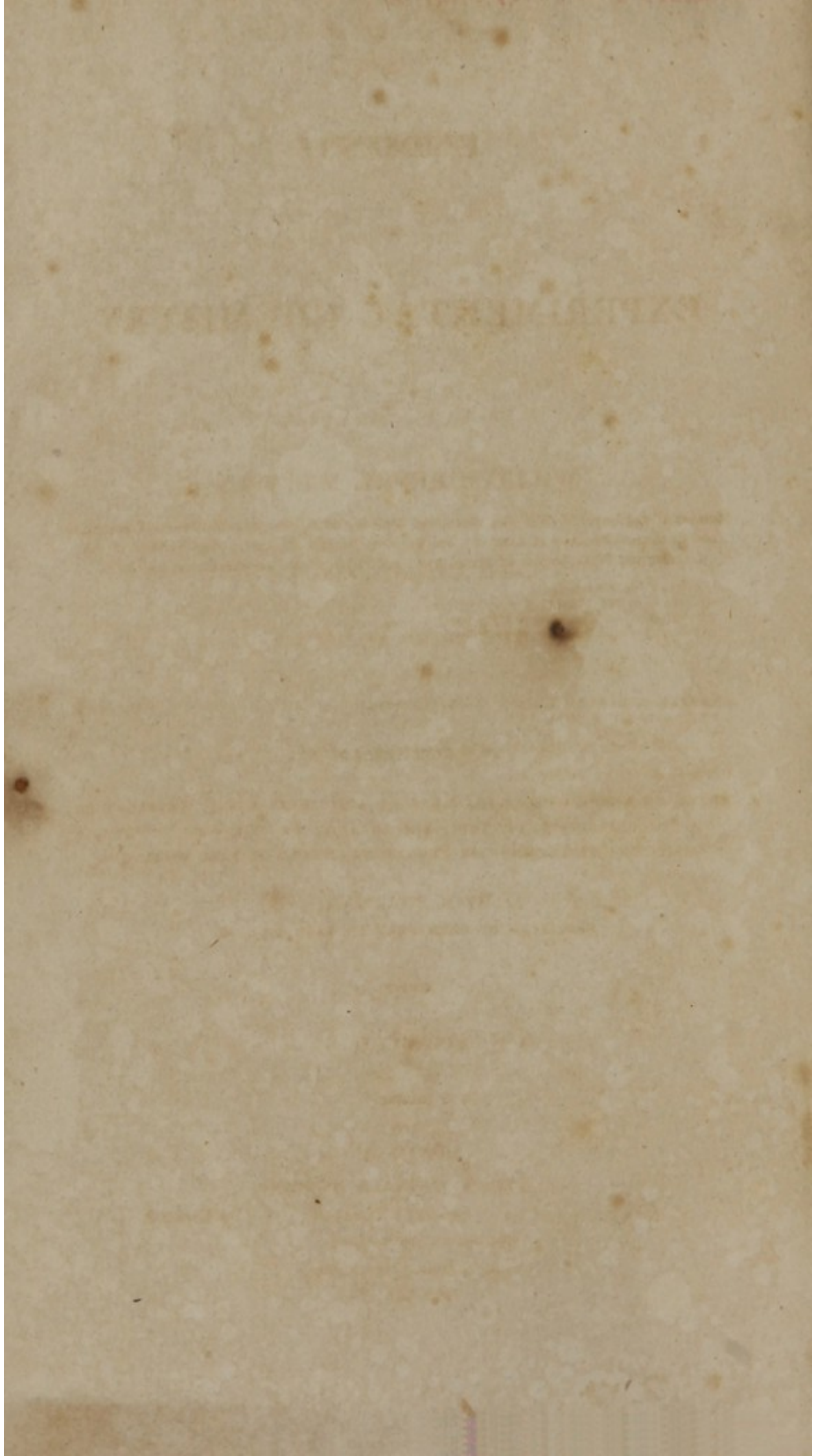
EXPERIMENTAL CHEMISTRY.

BY

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THE THIRD AMERICAN,

FROM THE SIXTH ENGLISH EDITION,

GREATLY ENLARGED BY THE AUTHOR ; AND ILLUSTRATED WITH NINE PLATES.

TO WHICH ARE ADDED,

NOTES, ON VARIOUS SUBJECTS ; WITH AN ADDITIONAL PLATE, ILLUSTRATING THE DECOMPOSITION OF THE FIXED ALKALIS, BY HEAT—AND A FRONTISPIECE, EXHIBITING THE PNEUMATIC CISTERN OF YALE COLLEGE,

BY B. SILLIMAN,

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VOLUME II.

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ELEMENTS

OF

EXPERIMENTAL CHEMISTRY.

PART I.

CHAPTER XVIII.

[See note 32 at the end of this vol.]

OF THE GENERAL PROPERTIES OF METALS.

THE metals compose a class of bodies, which are not more interesting from their application to the common arts of life, than from the facts which they contribute to the general principles of chemical science. Not more than seven or eight were known to the ancients; but the class has been enlarged, within the last century, by the discovery of twenty new ones. In addition to the recently discovered bases of the alkalis and earths, the following appear to have a sufficient claim to be considered as distinct metals.

1. Gold	8. Osmium	15. Bismuth	22. Molybdena
2. Platina	9. Copper	16. Antimony	23. Uranium
3. Silver	10. Iron	17. Tellurium	24. Tungsten
4. Mercury	11. Nickel	18. Arsenic	25. Titanium
5. Rhodium	12. Tin	19. Cobalt	26. Columbium
6. Palladium	13. Lead	20. Manganese	27. Cerium
7. Iridium	14. Zinc	21. Chrome	

Of a class comprehending so many individuals, it is not easy to offer a general description; but it will be found that they are all characterised by one or more of the following properties.

1. With the exception of the newly discovered bases of the alkalis and earths, they are distinguished by a high degree of specific gravity; the lightest of the metals (tellurium) being considerably heavier than the most ponderous of the earths. They are,

perhaps, the only solid bodies, whose specific gravity is affected by mechanical means ; or, in other words, whose particles can be brought permanently into a state of nearer approximation by external pressure.   In consequence of this property, several of the metals undergo material changes in their specific gravity, by the mechanical operations of rolling, hammering, &c.

2. They are opake, at least in the state in which they generally occur to our observation.   Gold, however, beat into leaves $\frac{1}{280000}$th of an inch in thickness, transmits a faint greenish light, when held between the eye and the direct light of the sun.

3. They possess various degrees of lustre, and it is of so peculiar a kind, that it has been termed by mineralogists the *metallic lustre*, and referred to as a known standard in the description of other minerals.   Some of the metals possess this property in so remarkable a degree, as to be applicable to highly ornamental purposes.   Polished steel takes place of all the metals in the perfection of its lustre ; but some of the class (as cobalt and nickel) appear to be susceptible of it in only a small degree.

4. The metals are excellent reflectors, not only of light but of caloric ; and hence they are the best materials for the composition of burning mirrors.   From the experiments of Mr. Leslie, they appear to possess this property in the following order, the highest number denoting the greatest reflecting power.

Brass - - - - - -	100
Silver - - - - - -	90
Tinfoil - - - - -	85
Planished block tin - - -	80
Steel - - - - - -	70
Lead - - - - - -	60
Tinfoil softened by mercury - -	50

In general, the reflecting power was found by Mr. Leslie to be proportional to the degree of polish, and to be impaired by every thing that diminished this quality.   A tin reflector, for example, had its reflecting power diminished nine tenths by being rubbed with sand paper.

5. Metallic bodies are, of all others, the best conductors of electricity.   Their property of electro-motion has already been described, in the chapter on the chemical agencies of electricity and galvanism.

6. They are, also, excellent conductors of caloric.

7. One of the most useful properties of the metals is their *malleability*, or capacity of being extended by the blows of a hammer.

In this quality, gold takes place of all the rest. The gold-leaf, which is sold in books, is so extremely thin, that less than five grains cover a surface of about 272¼ square inches ; and the thickness of each leaf does not exceed $\frac{1}{282020}$th part of an inch. All the metals, however, are not malleable. Gold, platina, silver, palladium, mercury (in its frozen state,) copper, iron, lead, tin, zinc, and nickel,* are the only ones to which this property belongs. The rest, on account of their brittleness, were formerly called *se-mi-metals*. But since, even in these, a diminishing progression of malleability may be observed, the distinction, though retained in common language, is very properly rejected from chemical and mineralogical systems.

8. All the metals that have been described as malleable (with the exception, perhaps, of nickel) are also *ductile*, or may be drawn out into wire. In this respect, also, gold appears to take precedence of the rest, for it may be drawn out into wire not thicker than a human hair.

9. Wires of the same diameter, but of different metals, are found to be capable of sustaining very different weights. This arises from their variable *tenacity*, which is estimated by gradually adding weights till the wire is broken. From the experiments of Count Sickingen, the following are the utmost weights, which wires of one tenth of an inch in diameter can support without breaking.

A wire of iron   supports 705 lbs. avoirdupois.
——————— copper ————— 387
——————— platina ————— 351
——————— silver ————— 239
——————— gold   ————— 191

The tenacity of tin is greatly inferior to that of gold ; and lead has even still less tenacity than tin.

10. Some of the malleable and ductile metals have, also, a high degree of *elasticity*. This property fits them for being applied to the mechanical purpose of springs. Steel and iron are, in this respect, superior to all other metals.

Beside the circumstances of agreement in their physical qualities, which have been enumerated, the metals resemble each other, also, in their chemical properties. Some of these resemblances it may be proper to state, for the purpose of avoiding unnecessary repetitions.

* On the authority of Richter.

The metals, so far as we know at present, are simple or elementary bodies, and may be arranged in the class of simple combustibles. They were formerly, indeed, considered, but on very insufficient evidence, as composed of a combustible base, peculiar to each metal, united with a general principle of inflammability, which received the name of *phlogiston*. When the metals are exposed to a strong heat, the first change which is produced in them is that they melt, or run into fusion. This effect takes place, in the different metals, at very different temperatures. Some of them may be made to boil, and are actually converted into vapour, at a heat considerably below redness; while others require a very intense heat for their fusion. By a sufficient elevation of temperature, it is probable, however, that they would all be volatilized; for platina itself, which does not melt at a less heat than 170° of Wedgwood, has been lately observed to boil, when placed in the focus of a powerful burning lens.* In some of the metals, no farther change is produced by the application of heat with the free access of air; and they return, on cooling, to their former condition. But others undergo a very remarkable change. Their cohesion, lustre, malleability, tenacity, and all the properties that have been described as characteristic of them, are destroyed. Though their *absolute* weight is increased, yet they become *specifically* lighter, and they are distinguished by a new train of properties not observed in the metals themselves.

These changes have been very differently explained, at different periods in the history of chemical science. On the theory of phlogiston, they were accounted for by assuming that the metals, during the process of exposure to air at a high temperature, abandon their phlogiston, which, it was supposed, unites with the air and renders it *phlogisticated*, and consequently unfit for supporting the combustion of other inflammable bodies. The hypothesis, however, could no longer be maintained, when it was proved that the metals, so far from losing weight, become heavier after the operation; and though various attempts were made, by modifications of the theory, to accomodate it to this fact, yet none of them can be considered as having been at all successful.

The theory, which is now almost universally admitted, as best explaining the phenomena in question, though suggested by the hints furnished by preceding discoveries, was first reduced to a systematic and consistent form by Lavoisier. The metals, accord-

* Annales de Chimie, lxix. 92

ing to the views of this enlightened philosopher, undergo the changes that have already been described, in consequence of the absorption of oxygen from the air. Hence, while the metallic body becomes heavier, the air, in which the process is performed, should sustain a proportional diminution of weight. That this is the fact, admits of being demonstrated ; and still more readily and satisfactorily, if we employ oxygen gas instead of common air. A certain quantity of the gas, (or the whole indeed, under favourable circumstances) disappears ; and the increase of weight in the metal is found, on examination, to be precisely equal to that of the gas which has been condensed. In some cases, we can even go farther ; and separate the oxygen from the metal by the mere application of heat, the oxygen being recovered in the state of gas, and the metal returning to a metallic state. More satisfactory evidence than this could scarcely be required of the nature of the change which takes place ; and it may be admitted, therefore, as an established truth, that metals lose their metallic form, in consequence of their combination with oxygen. The process has been called by Lavoisier *oxidation*, and the result of it an *oxide*. For the former term, however, Mr. Chenevix, influenced by reasons which are stated in his work on chemical nomenclature, has proposed to substitute that of *oxidizement*. In the following pages, I shall employ both these terms indiscriminately.

The phenomena and results of the oxidizement of metals are not the same in all cases, but differ very considerably with respect to different metals.

1. Some metals are oxidized by mere exposure to atmospheric air at the ordinary temperature, and even to air which has been deprived of its hygrometric water. Arsenic, manganese, and the new metals discovered by Mr. Davy, are perhaps the only ones which have been proved to possess this property. Others, it is true, as lead and copper, are changed by the action of the air, but extremely slowly, and not without the conjoined operation of moisture.

2. Other metals undergo this change, but not without a considerable increase of their temperature. Iron, zinc, copper, tin, &c. when heated to redness, lose their metallic lustre, and are slowly converted into oxides, the colours of which vary according as they have been obtained from different metals. In some instances, the process is accompanied with so abundant an extrication of light and heat, as to exhibit a vivid inflammation. This happens, chief-

ly, with some of the volatile metals.   Arsenic and zinc, for exam-
ple, when projected into a red-hot crucible, emit a brilliant flame.
In other metals, the process is unaccompanied by any remarkable
phenomena, and is known to have taken place only by its results.

3. With the exception of mercury, the metals, which have been
called perfect, (comprehending, also, gold, platina, silver, and pal-
ladium,) are not oxidized, even by the combined operations of air
and of an increased temperature.   Gold, silver, and other metals
of this kind, may be kept for many days in fusion, without under-
going any change.   That they have an affinity, however, for oxy-
gen, and are even capable of taking it from atmospheric air, is
proved by the effect of an electrical or galvanic battery.   By the
former, the wires of the perfect metals are, at the same moment,
dispersed into smoke and oxidized ; and by transmitting a power-
ful discharge, through any of the perfect metals beaten into thin
leaves, the metal burns with a remarkable degree of splendour.

4. All metals, that are oxidized by atmospherical air, are still
more readily converted to the same state by oxygen gas.   In ma-
ny cases a metal, which undergoes this change slowly and invisi-
bly by the action of air, takes fire in oxygen gas, and exhibits a
bright inflammation.   This remark applies to iron, for it has al-
ready been shown that a wire of this metal may be entirely con-
sumed in oxygen gas.

These are the most simple cases of metallic oxidizement.   In
order that the changes, which have been described, may take
place, it is only necessary that there should exist a stronger affin-
ity between oxygen and the metal, than between the oxygen and
light (and perhaps the electricity) which constitute the gas.   In
other cases, the phenomena are more complicated, and the metal
acquires oxygen by the decomposition of some other compound.
Of these sources of oxygen, the most important, if not the only
ones, are water, the acids, and other oxides ; or compounds
containing one or more of these substances.

I. Water gives up its oxygen to those metals only, which man-
ifest a powerful affinity for that basis, and, generally speaking, to
those which are most efficient in decomposing atmospherical air.
The newly discovered metals of Mr. Davy decompose it with a
rapidity, which amounts to actual inflammation ; but, in general,
the change is slow at common temperatures.   Iron filings, for ex-
ample, when moistened with water, and confined in an inverted
jar over mercury, become very gradually oxidized, and evolve

hydrogen gas.   But water, brought into contact with red-hot iron, is rapidly decomposed, and hydrogen gas is disengaged in torrents.

II. All those acids, in which oxygen has been proved to exist, and especially those which Dr. Thompson has called *supporters of combustion*, and the neutral salts containing them, are efficient means of oxidizing the metals.   In general, the less strong the affinity of the acid base for oxygen, the more rapidly is the metal oxidized.   Those acids, that have not been proved to contain oxygen (now indeed reduced, in consequence of Mr. Davy's discoveries, to one only, *viz.* the muriatic) are remarkably inert in their action on metals ; and the same inactivity belongs to other acids, in which the oxygen and base are held combined by a powerful affinity.   Thus concentrated sulphuric acid, at the temperature of the atmosphere, scarcely attacks any of the metals ; because the oxygen and sulphur, of which it consists, forcibly attract each other.   On the other hand, the nitric, nitro-muriatic, and oxy-muriatic acids, in which there exists a large quantity of loosely combined oxygen, readily abandon a part of it, and act on the metals with considerable energy.   Even the perfect metals are oxidized by the two last acids ; and thus we obtain proof that the resistance, which the perfect metals show to the action of oxygen gas, is not owing to their want of affinity for that basis, but to the predominance of other opposing forces.

Some of the acids, which do not, in their concentrated state, act upon metals, acquire the power of oxidizing them when diluted with water.   This is true of the sulphuric and muriatic acids, to either of which we may apply iron or zinc, without any change ensuing.   But on adding water, the metal disappears, and hydrogen gas is abundantly evolved.   Now it is a principle, to which no exception has yet been discovered, that a metal cannot, in its perfectly metallic state, unite with any acid.   In order to be dissolved, it must first be brought into the state of an oxide ; and in the case which has been just now stated, no substance, capable of furnishing oxygen, is in contact with the iron except water.   As an additional proof that water is, in this instance, the source of the oxygen, it has been ascertained that no portion of the acid is decomposed ; but that the same quantity of acid exists in combination with oxide of iron, as was originally submitted to experiment.

By measuring the quantity of hydrogen gas, evolved in experiments of this kind, it is not diffiult to calculate how much oxygen

the metal has acquired ; since every 15 parts by weight of hydrogen gas indicate the transference to the metal of 85 parts by weight of oxygen. Equal weights of different metals evolve different quantities of hydrogen gas, in consequence of their combining with different quantities of oxygen. If one metal, for example, in order to become soluble in sulphuric acid, require 40 *per cent.* of oxygen, and another only 20 *per cent.* the former will disengage twice as much hydrogen gas as the latter. The same metal, also, in different states, may evolve different quantities of hydrogen. If for example, the metal be already a little oxidized, it will set at liberty less hydrogen than if it were perfectly metallized. On this principle, the different proportions of real metal in several varieties of iron and steel have been investigated, the most perfectly metallized iron yielding, of course, the most hydrogen gas.

The phenomena, observed during the solution of a metal, and those attending the solution of its oxide, in the same acid, are essentially different. For the most part, a metal is dissolved with effervescence, an appearance always occasioned by the escape of gas. Iron it has already been stated, effervesces strongly during its solution in dilute sulphuric acid ; but the black oxide of that metal is taken up silently, and without any discharge of gas.

III. The metals may be oxidised by the transfer of oxygen from other metallic oxides. Thus when iron filings are distilled with the red oxide of mercury, the oxygen passes to the iron, and the mercury is revived or appears in a metallic state. In a similar manner, the oxides held in solution by acids, are decomposed by immersing, in the solution, other metals. When copper, for example, is immersed in a solution of nitrate of mercury (consisting of oxide of mercury and nitric acid) the latter metal is deprived of its oxygen by the former, and appears on the surface of the copper in a revived state. The nitrate of copper, which is thus produced, is precipitated by iron, which has a stronger affinity than copper for oxygen. A variety of similar examples might be given, in which the precipitating metal takes oxygen from that which is precipitated. In cases of this sort, it must be confessed that the comparative affinities of the acid for the oxides of the two metals have some share in the effect, but much less than the affinities of oxygen separately considered. The precipitated metal, also, is never quite pure, but contains a portion of the metal, which has caused the precipitation.

By an attentive examination of facts of this kind, Lavoisier has been able to deduce the proportion of oxygen necessary to the solution of different metals, according to this analogy : *As the quantity of the* PRECIPITANT *is to that of the* PRECIPITATED *metal, so is the quantity of oxygen necessary for the solution of the precipitated to that necessary for the solution of the precipitant.* Thus it has been found by experiment that 135 grains of mercury are necessary for the precipitation of 100 grains of silver from the nitric acid. It is evident, then, that 135 grains of mercury require for solution the same quantity of oxygen as 100 grains of silver; and, therefore, the quantity, necessary to dissolve 100 grains of mercury, is to that necessary for the solution of 100 grains of silver as 100 to 135. Now eight grains of oxygen are necessary to the solution of 100 grains of mercury ; and therefore 10.8 grains are required for the solution of 100 grains of silver. By an extension of the same experiments to other metals, Lavoisier formed a table of the quantity of oxygen necessary for the solution of all the metals ; but I omit giving it in this place, because subsequent discoveries have pointed out in it several inaccuracies.

Such are the principal means of effecting the oxidation of metals. Different individuals of the class, it has already been stated, combine with different proportions of oxygen ; and the same metal, it may now be added, is susceptible of different degrees or stages of oxidation. Iron, for example, when united with oxygen in the proportion of $22\frac{1}{2}$ grains to $77\frac{1}{2}$ of the metal, composes, according to Thenard, a *white* oxide ; with 24 parts of oxygen to 76 of metal, it constitutes a *black* oxide ; and with 31 parts of oxygen to 69 of iron, a *red* oxide. These different oxides of the same metal have not only different colours ; but each of them is characterized by a distinct train of chemical properties, and especially by different habitudes with respect to the acids. Thus the white and black oxides readily unite with muriatic and sulphuric acids; but the red oxide less easily. The salts with base of the two first oxides afford a white precipitate with triple prussiate of potash ; and none at all with the gallic acid or with sulphuretted hydrogen. But the salts, in which the iron is at the maximum of oxidation, give a deep blue compound with the triple prussiate, and a black one with the gallic acid.

It is an interesting question, whether the same metal is capable of uniting with oxygen, in all proportions between the maximum and minimum, or whether it does not rather combine with that

principle in a few proportions only, between which there are no intermediate compounds. Are there, for example, only two oxides of mercury, the *black*, consisting of 100 parts of metal united with four of oxygen ; and the *red*, composed of the same quantity of metal and eight parts of oxygen ? The determination of this point requires more precise and multiplied appeals to experiment, than have hitherto been made. But in most of those cases, where the question has been accurately investigated, different oxides of the same metal do appear to contain oxygen, in proportions which are simple multiples of each other ; and the fact will probably be established with respect to other oxides. It is by no means necessary, however, that the possible number of oxides of any one metal should be limited, as Proust has supposed, to two ; for it is perfectly consistent with the hypothesis that there may be three, four, or even a greater number.

It had been long known that of different oxides of the same metal, the one which contains a larger proportion of oxygen is capable of saturating more acid, than the one which contains less. To this principle an important addition has lately been proposed by Gay Lussac,* and supported by a variety of illustrations ; *viz. that the quantity of acid, which different metals require for saturation, is in direct proportion to the quantity of oxygen in their oxides.* Let us suppose, for example, that of any two metals, A combines with twice as much oxygen as B ; then, in order to neutralize the same quantity of a given acid, half the quantity of the oxide of A will be sufficient that is required of the oxide of B. Two of the illustrations, which are given of this principle, are furnished by the muriates of copper and the muriates of mercury. Corrosive muriate of mercury is composed of the red oxide of that metal, united with muriatic acid ; and the sub-muriate (calomel) consists of the black oxide, combined with the same acid. Now it is remarkable that, according to the experiments of Thenard, the oxygen in the red oxide is just double of that in the black; and that the acid in the corrosive muriate is, also, precisely double that in the sub-muriate. Similar facts have been ascertained by Proust, with respect to the two muriates of copper, as appears from the following statement.

The green muriate consists of
{
100 copper
24.57 oxygen
83.18 acid
}

* Mémoires d' Arcueil, ii. 159.

$$\text{White mu-}\atop\text{riate of}\left\{\begin{array}{l}\text{100 copper}\\\text{12.28 oxygen}\\\text{41.59 acid}\end{array}\right.$$

This principle, if it can be well established, will be an important step in chemical philosophy; and it derives additional probability from its coincidence with the theoretical views of Mr. Dalton. At present, however, it must be confessed, that the law has been deduced from much too small a number of facts; and it will require for its establishment an extension, to other metallic salts, of the same inquiries, which have produced the foregoing results of Proust and of Thenard.

The solubility of the metallic salts, it has been observed by Gay Lussac, bears a proportion to the quantity of oxygen in the oxides; and consequently to the quantity of acid, with which that oxide is combined. Salts, in which the metal is at the minimum of oxidation, are generally those which are most insoluble. This is the fact with respect to the salts of lead, silver, and mercury; for these are metals which, at the minimum of oxidisement, take very little oxygen, and consequently very little acid. Corrosive muriate of mercury, also, which contains the largest proportion of oxygen and acid, is much more soluble than the submuriate, in which both the oxygen and acid are present in considerably less quantity.

There is a certain state of oxidation, peculiar to the different metals, in which they are most readily acted upon by the several acids. Iron and manganese, for example, at the maximum of oxidizement, are altogether insoluble in nitric acid; but readily dissolve in it, when combined with a smaller proportion of oxygen. Even when once brought into combination with that acid, the oxide, by attracting a farther quantity of oxygen from the atmosphere or from any other source, is separated in the state of an insoluble precipitate. This principle explains the change, which is produced in solutions of iron, by keeping them exposed to air. The oxides of iron and manganese, saturated with oxygen, are soluble, however, in the less oxygenated acids; for example, in the sulphurous or nitrous, which first deprive the oxide of part of its oxygen, and then dissolve the less saturated oxide.

Beside the class of acids, which are the best solvents of the metals, alkaline solutions act upon metallic substances. The water, which holds the alkali in solution, is decomposed; its hydrogen is disengaged, and its oxygen transferred to the metal; and the

oxide, thus produced, is taken up by the alkaline liquor. The ox-
ides, ready formed, are also, in several cases, dissolved by liquid
alkalis. When a pure alkali is added to a metallic solution, the
metal is precipitated in the state of an oxide ; but the precipitate
is seldom quite free from alkali, and the metallic oxide, in a few
instances, instead of appearing in a separate form, is dissolved by
the alkali. Pure ammonia, for example, added to sulphate of cop-
per, affords a transparent blue liquor, which owes its colour to ox-
ide of copper dissolved by ammonia. When alkaline carbonates
are employed instead of pure alkalis, for the precipitation of me-
tallic solutions, the oxide combines with carbonic acid, and appears
in the state of a metallic carbonate.

The oxides, existing in metallic solution, are decomposed by
inflammable substances. Light only is sufficient for the decom-
position of some of them. Hydrogen gas, charcoal, sulphur, phos-
phorus, and the compounds of hydrogen with the three last bodies,
when brought into contact with the solutions of perfect metals at
common temperatures, attract the oxygen from the metal, and oc-
casion its appearance in a metallic form. In this way, several
beautiful appearances may be produced, which will be described
in treating of the individual metals.

The oxides themselves are decomposed when exposed to a
strong heat in contact with hydrogen, charcoal, or phosphorus.
The two first, or substances containing them, are chiefly employ-
ed for the decomposition of those oxides, which occur as natural
productions. The oxide, mixed with a portion of inflammable
matter, is exposed to an intense heat ; and, in order to obtain it
in a coherent mass, and not in the small grains which would oth-
erwise be formed, some substance is generally added, which is
capable of being melted and of allowing the metal to subside
through it. Substances of this kind are called *fluxes*, and the
process is termed the *revival* or *reduction* of the metal.

If only one oxide had existed of each metal, it would have been
easy, by applying the general principles of chemical nomencla-
ture, to have distinguished them by names sufficiently expressive
of their composition. But as the metals are susceptible of several
stages of oxidizement, it is difficult to find terms, which sufficient-
ly express the characteristic distinctions of several oxides of the
same metal ; and still more so, since it is not yet demonstrated,
whether the metals unite with oxygen in a few definite or in un-
limited proportions. The existence of only two oxides would

have greatly simplified their nomenclature; for, in this case, we might have applied the term *oxide* to the metal fully saturated with oxygen, and of *oxidule* to the compound at an inferior stage of oxidizement, as has been done by several of the French chemists. In the present state of the science, however, this nomenclature is inadmissible; and the specific name has been derived from some external character, chiefly from that of colour. Thus we have the white, black, and red oxides of iron; and the black and red oxides of mercury. This appears to me to be all that can be attempted, till the metallic oxides are better known. At some subsequent period, the denominations, which have been proposed by Dr. Thomson for the metallic oxides, may be advantageously adopted. When there are several oxides of the same metal (still supposing that the proportions of oxygen and metal in each are not indefinite) he has proposed the terms *protoxide, deutoxide, tritoxide,* &c. signifying that the metal is in its first, second, or third stage of oxidizement. Or if two oxides only of any metal are known, he suggests the appellation of *protoxide* for that at the minimum, and of *peroxide* for that at the maximum of oxidation.

A similar difficulty has been experienced, also, with respect to the neutral salts with metallic bases; for when different oxides of the same metal combine with a given acid, the resulting salts require to be distinguished by appropriate names. This has sometimes been done by prefixing the word oxygenized (or for brevity oxy-) to the salt containing the most highly oxidized metal; as the muriate and oxy-muriate of mercury. The latter term, however, is improper; because, in strictness, it can only be applied to the compounds of oxy-muriatic acid with different bases; whereas what is meant to be expressed is merely a compound of ordinary muriatic acid, with mercury in its highest state of oxidizement. If the principle assumed by Gay Lussac should be confirmed by farther investigation (*viz.* that the acid in metallic salts is proportional to the oxygen in the oxides,) it will be more easy to derive a specific name from the proportion of acid than from that of oxygen. Thus we shall have the muriate and sub-muriate of mercury. But till greater precision is acquired in our knowledge of this class of bodies, it may be well to continue to derive the specific name of the salt from some obvious quality; as the *green* and *red sulphates of iron,* the *white* and *green muriates of copper,* &c.

Besides the important class of compounds, which result from the union of metallic oxides with each other, the metals are capable, also, of entering into combination with some of the simple combustibles, and especially with hydrogen, sulphur, phosphorus, and charcoal. They afford, also, by uniting with each other, an interesting class of compounds called *metallic alloys*.

I. THE COMPOUNDS OF METALS WITH HYDROGEN are neither numerous nor of much importance. When water is decomposed by certain metals, at the same time that the oxygen combines with one portion, the hydrogen, which is disengaged in the state of gas, takes up a minute quantity of metal. This is the case, in a small degree, with iron; still more with zinc; and most remarkably with arsenic, the last of which affords a compound having several remarkable properties.

II. THE COMBINATIONS OF METALLIC BODIES WITH SULPHUR have been divided by Vauquelin* into three classes, *viz.* 1st, the compounds of metals with sulphur, which alone are with propriety called *sulphurets*; 2dly, the compounds of sulphur with metallic oxides, termed *sulphuretted oxides*; and 3dly, those of sulphuretted hydrogen with metallic oxides, which may be called *hydro-sulphuretted oxides*.

1. All the metals, with the exception of gold, zinc, and tin, are, in their metallic state, susceptible of combination with sulphur. In order to effect their union, it is sufficient that one of the bodies be brought into a fluid state; and as sulphur is readily fusible, a very moderate heat only is required for the purpose. Thus a mixture of 45 parts of iron filings with 15 of sulphur, or of 40 parts of copper filings with 15 of sulphur, when heated in a glass tube, combines the moment the fusion of the sulphur is accomplished. The phenomena are very remarkable, consisting in a sudden and bright glow, like that of intense ignition. During combination, however dry the materials may have been, it appears from the experiments of Mr. Clayfield† that a quantity of elastic fluid is liberated amounting to nine or ten times the bulk of the mixture, and consisting of sulphuretted hydrogen and sulphurous acid. The former, probably, arises from the sulphur, and the latter from the metallic filings, which may have been partially oxidized by the process of washing and drying. In these compounds,

* Annales de Chimie, xxxvii. 57.

† Note to Mr. Davy's paper on alkalis. (Philosophical Transactions, 1808.)

Mr. Davy is of opinion that the sulphur retains part of its hydrogen, and the whole of its oxygen.

In these compounds, the properties of the metals cease to be apparent; for the sulphurets are brittle; have colours different from those of the metals; and, when artificially formed, are destitute of lustre. The quantity of sulphur, with which different metals are capable of uniting, varies considerably. Mr. Kirwan has given the following table, the numbers in which are, however, to be considered as merely approximations to the truth.

100 grains of silver	unite with 15 of sulphur
——————— lead	——— 15
——————— bismuth	——— 17.6
——————— tin	——— 18
——————— mercury	——— 25
——————— copper	——— 25.4
——————— antimony	——— 29.8
——————— (native)	——— 35
——————— iron	——— 56

The same metal, also, is, in some instances, susceptible of uniting with different quantities of sulphur, and of affording compounds characterised by a different set of properties. Thus the compound, which consists of $62\frac{1}{2}$ iron and $37\frac{1}{2}$ sulphur is of a dark grey colour; has little or no lustre; is magnetic; and easily broken. But 53 parts of iron combined with 47 of sulphur form a compact substance, of sufficient hardness to strike fire with steel, and having so much lustre as to have been often mistaken by the ignorant for gold.

Metallic sulphurets can only be partially decomposed by heat; and though this assertion appears to be contradicted by the effect of roasting these compounds, yet it is to be considered that the metals, when heated with the contact of air, absorb oxygen, and thus lose their affinity for sulphur. The sulphuret of one metal may, in many instances, be decomposed by another metal. Thus when sulphuret of mercury is distilled with a proper proportion of iron filings, the sulphur passes to the iron, and the mercury comes over in a metallic state.

Concentrated sulphuric acid,* with the assistance of heat, acts upon metallic sulphurets, and is converted into sulphurous acid, which, being volatile, escapes. Metals, which, in their separate

* Berthollet, *Annales de Chimie*, xxv. 256.

state, were dissolved by dilute sulphuric acid, continue sensible to its action, after being combined with sulphur.

When dilute sulphuric acid, however, acts on such compounds, instead of hydrogen gas simply, we obtain sulphuretted hydrogen. It is chiefly the compounds with the minimum of sulphur that produce this effect; for the *super-sulphurets*, or those containing a farther proportion of sulphur, resist the action of this solvent.

Concentrated muriatic acid has no effect on sulphurets; but the diluted acid acts like the diluted sulphuric. Nitric acid is decomposed by the metallic sulphurets; nitrous gas is disengaged, and sulphur is precipitated.[*] In this case, though all nitric acid contains water, yet sulphuretted hydrogen is not formed, because the acid yields its oxygen more easily than water.

Sulphurets, composed of these metals, which powerfully attract oxygen, and the oxides of which have moreover an affinity for sulphuric acid, absorb oxygen from the atmosphere, and pass to the state of *sulphates*. In this way most of the sulphate of iron is formed, which occurs in commerce. But if the metal has either a strong affinity for sulphur or a weak one for oxygen, then the conversion into a sulphate does not happen, as in the sulphurets of copper, antimony, and mercury.[†] The sulphuret of iron containing a full proportion of sulphur resists, also, the conjoined action of air and moisture.

2. In general, the metals have a stronger affinity than their oxides for sulphur. But there are a few cases, in which certain metals are incapable of combining with sulphur, till they are brought into the state of oxides. These are chiefly zinc, mercury, and manganese, the compounds of which with sulphur may be called *sulphuretted oxides*. Other metals, also, are capable of affording similar compounds; but in general their affinity for sulphur diminishes, in proportion to the quantity of oxygen which they hold in combination.

These compounds act on acids, somewhat differently from the mere sulphurets. If the metal be only oxidized at its minimum, they yield sulphuretted hydrogen with diluted muriatic and sulphuric acids, and nitrous gas with nitric acid. But in their perfectly oxidized state, they dissolve without effervescence, and the sulphur remains unaltered.

3. Sulphuretted hydrogen enters into combination with a few of the metals, with mercury and silver for example; but it unites,

* Vauquelin, loc. cit. 65.   † Berthollet, loc. cit. 256.

in general, more readily and permanently with their oxides. From such compounds, the sulphuretted hydrogen is detached in a gaseous state by some concentrated acids, which seize the metallic oxide. Most of the sulphuretted oxides, also, undergo, in process of time, spontaneous decomposition, in consequence of the union of the hydrogen and oxygen which they contain, and which, by combination, form water. When this happens, the oxide is partly reduced, and the sulphur unites with the less oxidized metal. Hence the same sulphuretted oxide varies in composition, according to the period which has elapsed since its preparation.

When we precipitate a metallic solution by sulphuretted hydrogen alone, or by its compound with alkalis, we obtain either a metallic sulphuret or a hydro-sulphuret. In the first case, the hydrogen of the sulphuretted hydrogen takes all the oxygen of the oxide; and the sulphur forms a true sulphuret with the reduced metal. In the second case, the sulphuretted hydrogen unites directly with the oxide, without decomposing it, and its proportion is such that the hydrogen is sufficient to saturate all the oxygen of the oxide. The quantity of hydrogen, then, which is destroyed, or may be destroyed, depends on the state of oxidizement of the metal, and so also does the quantity of sulphur. Now if metals, as appears probable, are susceptible of oxidation in only a few determinate degrees, it follows that by precipitations of this kind, we may obtain metallic sulphurets with fixed proportions, which may be easily calculated from the known quantity of oxygen in the oxide, and the known composition of sulphuretted hydrogen.* Thus the law of fixed proportions will be extended to the compounds of metals with sulphur ; and another step will be made, towards establishing the important general principle in chemical philosophy, which has been so ably illustrated, in other cases, by Mr. Dalton.

4. Hydroguretted sulphurets of metals and their oxides may be obtained by precipitating metallic solutions with the hydroguretted sulphurets of alkalis. Their composition and properties, however, have not hitherto been fully investigated.

III. Several metals have an affinity for phosphorus, and form a class of compounds called METALLIC PHOSPHURETS. The best method of effecting this combination is to expose the metals to heat, in contact with phosphoric acid and charcoal. The char-

* Gay Lussac, *Memoires d' Arcueil*, ii. 175.

coal deprives the phosphorus of oxygen ; and the de-oxygenized phosphorus unites with the metal. Metals, however, that have a strong affinity for oxygen, decompose the phosphoric acid, and unite with its base, without the intervention of charcoal. The metallic phosphurets have not hitherto been applied to any useful purpose ; and it is sufficient, therefore, to refer to the description of them by Pelletier, in the first and thirteenth volumes of the *Annales de Chimie.*

IV. The compounds of metals with carbon are called CARBURETS. That of iron and carbon, the properties of which vary according to the proportion of the two ingredients, is the only one of importance. It will be described in its proper place.

V. The metals are, for the most part, capable of uniting with each other. For this purpose, they require to be brought into a state of fusion ; and, even when melted, considerable care is necessary to form a permanent compound. If one metal is considerably heavier than the other, it is apt to sink to the bottom of the fluid mass. Nothing can show this in a more striking manner, than a fact which has been stated by Mr. Hatchett. He found that when gold, which has been melted with a proportion of copper or other metals, is cast into bars, the moulds for which are placed vertically, the lower part of the bar contains more gold in proportion than the upper part.

There are a few of the metals that do not unite by being fused together. This is the case with lead and iron ; but even in such cases we are scarcely, perhaps, entitled to deny all affinity ; for some of the metals, which were formerly thought incapable of combination, have been made to combine by circuitous processes. This is the fact with respect to iron and mercury.*

In the new nomenclature, the word ALLOY is retained as a general term for all combinations of metals with each other ; and the specific name is derived from that of the metal, which prevails in the compound. Thus in the *alloy of gold with silver*, the gold is to be understood as being in greatest proportion ; in the *alloy of silver with gold*, the silver is the principal ingredient. The compounds of mercury with other metals, at a very early period of chemistry, were called AMALGAMS, and as the name does not lead to any erroneous notions, it may still be retained to denote this sort of alloys.

The metals in general are capable of uniting with each other

* Aikin, in Philosophical Magazine.

in unlimited proportions; but in a few instances, it appears prob-
able, though it is not absolutely proved, that they unite in certain
proportions only. By combination, they undergo a remarkable
change of qualities ; and the resulting properties, when of a kind
that can be easily appreciated, are found to bear no proportion
whatsoever to those of the separate metals.

1. The specific gravity of an alloy is seldom the mean of those
of its component parts. Thus an alloy of silver with copper or
tin, or one of silver or gold with lead, has a greater than the mean
specific gravity. An alloy, also, of silver with mercury, though
the former metal is specifically lighter than the latter, possesses
so much acquired density as to sink in quicksilver. In other cas-
es, on the contrary, the specific gravity of the compound falls short
of the mean of that of its components, or there appears to be a de-
gree of dilatation, as in the alloys of gold with copper, iron, or tin.
To estimate exactly, however, either the increase or diminution
of density, requires an attention to several circumstances.*

2. The ductility and malleability of metals is generally changed
by combination ; and, for the most part, these qualities are im-
paired. Even two metals, which separately are both malleable
and ductile, are rendered brittle by combination. This is very re-
markably the case with an alloy of gold and lead, the latter of
which, even in the trivial proportion of half a grain to an ounce
of gold, is quite destitute of tenacity. In such cases, it has been
supposed that a true chemical union does not take place, and that
the newly added metal is merely mechanically interposed between
the particles of the other, the cohesion of which it thus impairs.
This explanation, however, can scarcely be admitted as satisfacto-
ry ; and, among other arguments in proof of the existence of
chemical union, it may be remarked, that gold is rendered brittle
by being kept in fusion in the vicinity of melted tin, the vapour of
which it seems capable of attracting.

3. The hardness of metals is varied by combination. Gold, by
combination with a small quantity of copper, and silver by a mi-
nute proportion of the same metal, acquire such an increase of
hardness that these additions are always made to gold or silver
which is to be exposed to wear. By a small addition of gold, iron
is said to gain so much hardness, as to be even superior to steel
for the fabrication of cutting instruments.

4. Change of colour is a common effect of the combination of

* See Aikin's Dictionary, article Alloy.

metals. Arsenic, for example, which resembles steel, and copper which has a red colour, afford a compound which has nearly the whiteness of silver.

5. The fusibility of compound metals is different from what might have been inferred from that of their components. Platina, for example, is rendered easily fusible by arsenic, and a compound of lead, tin, and bismuth melts at a temperature below that of boiling water, though the most fusible of the three (bismuth) requires for fusion a much higher degree of heat. This is the principle of *solders*.

6. Metals have their volatility increased by being combined with other metals, which are more volatile than themselves. Gold, separately, requires an intense heat for its volatilization ; but when an amalgam of gold with mercury is distilled, a quantity of gold passes over with the quicksilver.

7. By chemical union with each other, the metals have their tendency to combine with oxygen considerably increased, partly in consequence of the diminution of their cohesion, but partly, also, perhaps, in consequence of their forming a galvanic combination. Lead, when amalgamated with mercury, is oxidized by merely shaking the compound with water. Lead and tin, melted together, acquire such an increase of affinity for oxygen, that, at the moment of combination, they actually inflame. By the oxidation of either ingredient in any of these alloys, the compound is destroyed. The oxide of lead, for example, separates from mercury in the form of a black powder. Hence, also, a pellicle of oxide is generally observed on the surface of melted solders, which is renewed as soon as it is removed.

From a comparison of the resemblances among metals, both as to physical and chemical properties, several arrangements of them have been formed into smaller classes. Besides the subdivisions, which have been already mentioned, into noble and base metals, and into entire metals and semi-metals, other classifications have been contrived. Fourcroy has proposed to divide them into five orders. 1. The *brittle and acidifiable* includes four species, *viz.* arsenic, tungsten, molybdena, and chrome. 2. The *brittle and simply oxidizable* are seven (nickel having been transferred by Richter to a different class,) *viz.* titanium, uranium, cobalt, manganese, bismuth, antimony, and tellurium. 3. The metals, that are *oxidizable and imperfectly ductile*, are mercury and zinc. 4. The *ductile and easily oxidizable* are tin, lead, iron, and

copper. 5. The *very ductile and difficult of oxidizement* are silver, gold, palladium, and platina.

A better arrangement, however, appears to me to be that which has been proposed by Dr. Thomson, in the third edition of his System of Chemistry. He divides the metals into four classes. The FIRST CLASS comprehends the *malleable metals*, which are fourteen in number, *viz.* gold, platina, silver, mercury, palladium, rhodium, iridium, osmium, copper, iron, nickel, tin, lead, and zinc. The SECOND CLASS includes the *brittle and easily fused, viz.* bismuth, antimony, tellurium, and arsenic. The THIRD CLASS, metals *that are brittle and difficultly fused.* These are cobalt, manganese, chrome, molybdena, uranium, and tungsten. The FOURTH CLASS are called *refractory metals ;* because they have never yet been exhibited in a perfectly metallic form, but always in combination with more or less oxygen. These are titanium, columbium, and cerium.*   In this order, I shall now proceed to describe the individual metals.

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FIRST CLASS.
MALLEABLE METALS.
SECTION I.
Gold.

I. THE external qualities of gold are the following :

1. It has an orange or redish yellow colour ; and may be brought to assume a degree of lustre inferior only to that of steel, platina, silver, and mercury.

2. Its specific gravity varies a little according to the mechanical processes, which it has undergone ; but it may be stated, on the average, at 19.3.

3. It exceeds all other metals in ductility and malleability, and may be beaten into leaves $\frac{1}{280000}$th of an inch in thickness.

4. It is considerably tenacious ; for a wire only $\frac{78}{1000}$ths of an inch diameter will sustain a weight of 150lbs.

II. Gold may be melted by a moderate red-heat ; *viz.* at about 32° of Wedgwood's pyrometer, or 1300° Fahrenheit. The intense heat of a glass-house furnace has no other effect than to keep it in fusion. And even exposure to Mr. Parker's powerful

* Tantalium has lately been shown by Dr. Wollaston to be identical with columbium.

burning lens, for several hours, occasioned no loss of weight. Af-
ter fusion, it crystallizes in short quadrilateral pyramids.

III. Pure gold is not oxidized by exposure to heat with the ac-
cess of air; but it may be brought to the state of a purple oxide
by transmitting, through gold leaf, either a powerful electrical or
galvanic discharge. Besides this oxide, another may be obtained
in a higher stage of oxidizement, the colour of which is yellow.
The latter oxide contains about ten *per cent.* of oxygen. By ex-
posure to a strong heat, it loses a part, and becomes the purple
oxide.

IV. Gold is not acted on by sulphuric, nitric, or muriatic acid,
even at the boiling temperature.

V. It is dissolved, however, by nitro-muriatic acid, and also by
the oxygenized muriatic acid. A thin sheet of gold introduced
into the latter acid, when in a gaseous state, takes fire and burns.

VI. The NITRO-MURIATE OF GOLD gives a purple stain to the
skin, and is susceptible of crystallization.

It is decomposed by alkalis A solution of pure ammonia sep-
arates an oxide of gold, and a portion of ammonia, uniting with
the oxide, forms a compound which detonates very loudly in a
gentle heat, and is termed *fulminating gold.*

To obtain this compound, add a solution of ammonia in water,
or the pure liquid ammonia, to diluted muriate of gold; a precip-
itate will appear, which will be re-dissolved if too much alkali be
used. Let the liquid be filtered, and wash the sediment, which
remains on the filter, with several portions of warm water. Dry
it by exposure to the air, without any artificial heat, and preserve
it in a bottle, closed, not with a glass-stopper, but merely by
a cork. A small portion of this powder, less than a grain in
weight, being placed on the point of a knife, and held over a
lamp, detonates violently. The precise temperature, which is
required, is not known, but it appears to exceed 250° Fahrenheit.
At the moment of explosion, a transient flash is observed. The
principal force is exerted downwards; and hence two or three
grains, exploded on a pretty strong sheet of copper, will force a
hole through it. Neither electricity nor a spark from the flint
and steel are sufficient to occasion its detonation; but the slight-
est friction explodes it, and serious accidents have happened from
this cause.

This detonation is explained as follows: Fulminating gold is
composed of an oxide of that metal, combined with ammonia.

When its temperature is raised, the ammonia is decomposed; the hydrogen of the alkali unites with the oxygen of the oxide, and reduces the gold to a metallic state; and nitrogen gas, and probably aqueous vapour, are liberated in a highly expanded state. The violent impulse of these aëriform products, on the surrounding atmosphere, appears to be the cause of the loud noise that is occasioned by the explosion of this compound. A similar explanation may be applied to other fulminating compounds of metallic oxides with ammonia; such as those of silver and mercury, which will be described hereafter.

Fixed alkalis throw down, from nitro-muriate of gold, the yellow oxide already alluded to.

VII. The solution of gold is also decomposed by certain combustible bodies, which attract the oxygen from the gold, and restore it to a metallic state. (a) Into a dilute solution of gold,* contained in a glass jar, put a long narrow slip of charcoal, and expose the whole to the direct light of the sun. The gold will be revived, and will appear on the charcoal in a metallic state, exhibiting a very beautiful appearance. The same change ensues without light, if the solution be exposed to a temperature of 212°.

(b) Moisten a piece of white taffeta ribband, with the dilute solution of gold, and expose it to a current of hydrogen gas from iron filings and dilute sulphuric acid. The gold will be reduced, and the ribband will be gilt with the metal. By means of a camel's hair pencil, the gold may also be so applied as to exhibit regular figures, when reduced.

(c) The same experiment may be repeated, substituting phosphuretted hydrogen for common hydrogen gas. The reader, who wishes for a detail of various experiments of a similar kind, may consult an Essay on Combustion, by Mrs. Fulhame, published by Johnson, London, 1794, and also Count Rumford's paper, in the Philosophical Transactions, 1798, page 449.

VIII. Gold is precipitated from muriatic acid, in a metallic form, by a solution of green sulphate of iron.

IX. When a sheet of tin is immersed in a solution of nitro-muriate of gold, the oxide of gold is precipitated of a purple colour; and, when scraped off and collected, forms the *purple powder of Cassius*, much employed in enamelling. Or the metallic salt,

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* The nitro-muriate of gold, employed in these experiments, should be previously evaporated to dryness, in order to expel the superfluous acid, and afterwards dissolved in distilled water.

largely diluted with water, may be put into a glass vessel with a few pieces of grain tin. In a short time, the liquor will become of the colour of red wine, and a very light flocculent precipitate will begin to separate, leaving the liquor clear. This, when well washed and dried, has a deep purple colour, and is the precipitate of Cassius. The same precipitate is obtained by mixing a solution of gold with a recently made solution of tin in muriatic acid.

X. Gold is precipitated from its solvent by ether, but the oxide of gold is instantly re-dissolved by the ether, and forms the ethereal solution of gold. This solution is advantageously applied to the gilding of steel scissars, lancets, and other instruments, which it protects from rust with a very small expenditure of gold.

XI. Sulphurets of alkalis unite with gold both in the dry and humid way. To exhibit this, some leaf-gold may be digested, with heat, in a solution of sulphuret of potash.

XII. The methods of purifying gold, by the operations of cupelling and quartation, would lead into too long details. They are very perspicuously described by La Grange, in the 44th chapter of his Manual, and in Aikin's Chemical Dictionary, article Gold. To the former work ; to Lewis's Philosophical Commerce of the Arts ; and to Mr. Hatchett's paper, in the Philosophical Transactions for 1803, I refer also for information respecting the alloys of gold with other metals. It may be proper, however, to add that gold, which is too soft, in its pure state, for many purposes, has its hardness greatly increased by being melted or alloyed with a small proportion of copper. It is a singular fact, that some kinds of copper, which do not themselves appear defective in any respect, totally destroy the ductility of gold. This appears to be owing to the contamination of the copper with a very small quantity of lead and antimony, of either of which metals only about $\frac{1}{1920}$th in weight is sufficient to produce this injurious effect.

The degree of purity of gold is expressed by the number of parts of that metal, contained in 24 parts of any mixture. Thus, gold, which, in 24 such parts (termed *carats,*) contains 22 of the pure metal, is said to be 22 carats fine. Absolutely pure gold, using the same language, is 24 carats fine : and gold, alloyed with an equal weight of another metal, 12 carats fine.

SECTION II.
Platina.

I. PLATINA, in the state in which it reaches this country, is contaminated by the presence of eight or ten other substances; and, in fact, is merely an ore of platina. It had been discovered in no other places than Choco and Santa Fé, in South-America, until about two years ago, when Vauquelin detected it in some grey silver ores from Estremadura ; and, more lately, it has been brought from the gold mines of Brasil. The general aspect of the ore of platina is that of small grains or scales, of a whiter colour than iron, and extremely heavy. Various processes have been contrived for its purification (see Aikin's Dictionary, article Platina ;) but the one, which is the most simple and practicable, appears to me to be that of Count Moussin Poushkin, communicated by Mr. Hatchett in the ninth volume of Nicholson's Journal.* It is unnecessary, however, to detail these processes ; as the metal may now be had, in a pure state, at a reasonable price ; among other places, at Cary's, No. 182, Strand, London.

II. Platina has the following properties :

1. It is a white metal, resembling silver in colour, but greatly exceeding it, and indeed all other metals, in specific gravity, which may be stated at 22 or 23.

2. It is extremely difficult of fusion. It may be melted, however, by the blow-pipe, with the aid of oxygen gas.

3. It is not oxidized by the long-continued and concurrent action of heat and air. To obtain its oxides, we must have recourse to a circuitous process. The nitro-muriate of platina is to be decomposed by lime-water, and the precipitate re-dissolved in nitric acid. This solution being evaporated, and heated so as to drive off the acid, a brown powder remains, which is the oxide of platina *at the maximum*, and which contains in 100 parts 13 of oxygen. This oxide, very carefully heated, passes to a green colour, and loses six parts of oxygen, seven only remaining, combined with 93 of metal.

4. Platina has the property of *welding*,† which belongs to no other metal but this and iron.

* A process for purifying platina, by the intermediation of zinc, is described by Descotils in the 64th volume of the *Annales de Chimie*, page 334.

† Two pieces of wrought iron, raised to a white heat, become covered with a kind of varnish ; and, when brought into contact, may be permanently united by forging. This is called the welding of iron.

5. It is not acted on by any other acid than the nitro-muriatic and oxygenized muriatic. The former is best adapted to effect this solution. Sixteen parts of the compound acid are to be poured on one of the laminated metal, and exposed to heat in a glass vessel; nitrous gas is disengaged, and a redish-coloured solution is obtained, which gives a brown stain to the skin.

6. The muriate of platina may be crystallized by careful evaporation. The salt has a very acrid taste, and is deliquescent. It is decomposed by heat, and an oxide of platina remains, which is reduced to a metallic form by ignition with charcoal.

7. The muriate of platina has the characteristic property of being precipitated by a solution of muriate of ammonia. By this character, platina is distinguished from all other metals, and may be separated when mingled with them in solution. The precipitate, thus obtained, is decomposed by a strong heat, and leaves pure platina.

8. Muriate of platina is not precipitated by prussiate of potash, nor by sulphate of iron. If any precipitate ensue, it is owing to contamination with other metals.

9. It is precipitated of a dark green colour by the gallic acid as present in tincture of galls. The precipitate becomes gradually paler by standing. (La Grange, ii. 272.)

10. When pure potash is poured into the muriatic solution, a precipitate ensues, which is not an oxide of platina, but a triple compound of that oxide with the alkali and acid. With soda, also, it forms a triple combination. This is best obtained, by adding to nitric acid, in a retort, platina, with twice its weight of muriate of soda, and applying heat till about four fifths of the fluid have come over. The remaining liquor forms, on cooling, fine prismatic crystals, sometimes four or five inches long; and either reddish-brown, like titanium; yellow, like amber; or of a beautiful coquelicot colour. (Nicholson's Journal, 8vo. ix. 67.)

11. Muriate of platina is decomposed by sulphuretted hydrogen, which throws down a brown precipitate. It is decomposed, also by ether, and an etherized solution of platina is obtained; which may be applied to the same uses as the similar solution of gold.

12. Platina is acted upon by fusion with nitrate of potash, and also with pure fixed alkalis. The latter property diminishes considerably the utility of platina as a material for crucibles.

13. The most delicate test of the presence of platina is muriate

of tin. A solution of platina, so dilute as to be scarcely distinguishable from water, assumes a bright red colour, on the addition of a single drop of the recent solution of tin.

14. Platina has been discovered by Dr. Wollaston to be a remarkably slow conductor of caloric. When equal pieces of silver, copper, and platina, were covered with wax, and heated at one end, the wax was melted $3\frac{1}{4}$ inches on the silver; $2\frac{1}{2}$ on the copper; and 1 inch only on the platina. Its expansion by heat is considerably less than that of steel; which, between the temperatures of 32° and 212° is expanded about 12 parts in 10,000, while the expansion of platina is only about 10. From trials made by Mr. Scott of Dublin, it appears to possess sufficient elasticity to be applicable to the making of pendulum springs for watches. (Nicholson's Journal, xxii. 148.)

SECTION III.

Silver.

SILVER is a metal, which admits of a degree of lustre, inferior only to that of polished steel. Its specific gravity, after being hammered, is 10.51. In malleability, ductility, and tenacity, it exceeds all the metals, except gold. Its fusing point, as determined by Dr. Kennedy, is 22° of Wedgwood's pyrometer. By considerably raising this heat, it may be volatilized; and, by slow cooling of the fused mass, it may be made to assume a regular crystallized form.

Its chemical properties are the following :

I. Silver is difficultly oxidized by the concurrence of heat and air. The *tarnishing* of silver is owing not to its oxidation merely, but to its union with sulphur, as Proust has satisfactorily shown.

II. It is acted on by sulphuric acid, which, when assisted by heat, oxidizes and partly dissolves it. The sulphate of silver, however, which is very useful as a test, is better prepared by dissolving in sulphuric acid the carbonate of silver, precipitated from the nitrate by carbonate of soda. It forms small brilliant and needle-shaped crystals, which require for solution a large quantity of water.

III. Nitric acid diluted with from two to four parts of water, dissolves silver with a disengagement of nitrous gas. If the silver be pure, the solution is colourless, otherwise it has a green hue. [See note 33, at the end of this vol.] According to Proust,

nitrate of silver already saturated, if boiled with powdered silver, dissolves an additional quantity; and a solution is obtained, in which the silver is oxidized only at a minimum. This sub-nitrate, he observes, possesses different properties from the common one. (Nicholson's Journal, xv. 376.)

IV. Muriatic acid does not act on silver; yet this acid takes oxide of silver from others. Thus when muriatic acid is added to nitrate of silver, a white curdy precipitate falls down in great abundance. This precipitate is decomposed by light; for, when exposed to the direct rays of the sun, its colour becomes gradually darker. (See chap. iv. par. v.) If fused by a gentle heat, it forms a semi-transparent mass of the consistence of horn, called luna cornea, or horn silver.

The composition of muriate of silver has been variously stated. According to Gay Lussac 100 grains of silver combine with 7.60 oxygen and 25.71 acid. Other chemists have given different proportions, as appears from the following table.

	Acid.	Base.
100 parts, according to Kirwan - - - -	16.54	83.46
—————————————— Chenevix - - - -	17	83
—————————————— Zaboada - - - -	17.7	82.3
—————————————— Proust - - - -	18	82
—————————————— Dr. Marcet - - -	19.05	80.95
—————————————— Gay Lussac - - -	19.28	80.72
—————————————— Berthollet - - -	17.5	82.5

These differences may, perhaps, in part but not entirely, be accounted for, by the different states of dryness of the muriate of silver. A hundred grains, I have found, dried during twenty-four hours, at a temperature between 212° and 300° Fahrenheit, lose barely a grain by fusion. On the whole, I should be disposed to consider the determinations of Dr. Marcet and Gay Lussac as most entitled to confidence.

Muriate of silver is decomposed by fusion with desiccated carbonate of soda. Mix one part of the former with three of the latter salt, and let the mixture be fused in a crucible. When cold, the silver will be found reduced at the bottom of the crucible; break the mass, and separate the metal. From 100 grains of the muriate, barely 75 of pure silver are obtained. This is one of the best modes of procuring silver in a state of purity.

V. A solution of nitrate of silver stains animal substances a deep black. Hence it has been applied to the staining of human

hair; but, when thus employed, it should be very much diluted, and used with great caution, on account of its corrosive quality.

White paper, or white leather, when stained with a solution of nitrate of silver, in the proportion of ten parts of water to one of the salt, undergoes no change in the dark; but when exposed to the light of day, it gradually acquires colour, and passes through a succession of changes to black. The common sun-beams, passing through red glass, have very little effect upon it; yellow and green are more efficacious; but blue and violet produce the most decidedly powerful effects. Hence this property furnishes a method of copying paintings on glass, and transfering them to leather or paper. The process is described by Mr. T. Wedgwood, in Nicholson's Journal, 8vo. iii. 167.

By a similar process, ivory may be covered with silver. Let a slip of ivory be immersed in a dilute solution of pure nitrate of silver, till the ivory has acquired a bright yellow colour. Then remove it into a tumbler filled with distilled water, and expose it to the direct light of the sun. After two or three hours exposure, it will have become black; but on rubbing it a little, the surface will be changed into a bright metallic one, resembling a slip of pure silver. As the solution penetrates deep into the ivory, the bright surface, when worn away, is replaced by a succession of others.

VI. The solution of nitrate of silver, when evaporated, forms regular crystals. These crystals fuse when heated; and being poured, in this state, into moulds, form the common *lunar caustic.* Fused nitrate of silver, according to Proust is composed of

$$
\begin{array}{ll}
\text{Silver} & 64 \\
\text{Oxygen} & 6
\end{array} \Big\} \ 70
$$

$$
\text{Nitric acid} \quad 30
$$

$$
\overline{\quad 100 \quad}
$$

VII. Nitrate of silver is decomposed by other metals. Thus the surface of a plate of copper to which the solution is applied, becomes plated over with silver. If a little mercury be poured into a bottle filled with this solution, and the bottle be left some time undisturbed, the silver is precipitated in a beautiful form, resembling the branches of a tree, which has been termed *Arbor Dianæ.* The most successful process for obtaining this appearance, Baumé assures us, is the following : Mix together six parts of a solution of silver in nitric acid, and four of a solution of mer-

cury in the same acid, both completely saturated. Add a small quantity of distilled water; and put the mixture into a conical glass, containing six parts of an amalgam made with seven parts of mercury and one of silver. At the end of some hours, there appears on the surface of the amalgam a precipitate in the form of a vegetation. According to Proust, however, this complicated process is quite unnecessary; and all that is required is to throw mercury into nitrate of silver very much diluted. A beautiful arborization of reduced silver, he observes, will be produced without difficulty.*

VIII. The solution of silver is decomposed by charcoal, and by hydrogen gas and its compounds. This may be shown by experiments precisely similar to those already directed to be made with muriate of gold. A stick of clean phosphorus, also, immersed in a dilute solution of nitrate of silver, in the course of a few days becomes beautifully gilt.

IX. Precipitate nitrate of silver by lime-water, and thoroughly edulcorate and dry the precipitate. Let this be afterward put into a vessel of the purest liquid ammonia. It will then assume the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air. This is the celebrated compound termed *fulminating silver*, which detonates with the gentlest heat, and even with the slightest friction. When once prepared, no attempt must be made to enclose it in a bottle, and it must be left undisturbed in the vessel in which it was dried. Great caution is necessary in the preparation of this substance, and in making experiments on it. It even explodes, when moist, on the gentlest friction.

X. A new detonating compound of silver, formed by a process similar to that employed in making the fulminating mercury of Mr. Howard, has lately been described by Descotils (Nicholson's Journal, xviii. 140.) It is prepared by adding alcohol, to a heated solution of silver in nitric acid, while the solution is yet going on. Considerable effervescence arises; the liquor presently becomes turbid; and a heavy, white, crystalline powder falls down. This, when washed and dried, is the *detonating silver*. Heat, a slight blow, or long continued friction, causes it to inflame with a brisk detonation. Pressure alone is not sufficient, unless very powerful. It detonates by the electric spark, and is set on fire with an explosion by concentrated sulphuric acid. Both in the preparation

* See Count Rumford's papers, Philosophical Transactions, 1798.

of this substance, and in experiments on its detonation, much caution is necessary; and only very small quantities should be employed. This preparation, I find, was originally discovered by Mr. Howard. In repeating his process, Mr. Cruickshank dissolved 40 grains of silver in two ounces of strong nitric acid diluted with an equal weight of water. Then by heating the solution with two ounces of alcohol, he obtained 60 grains of a white powder, which detonated violently. [See note 33, at the end of this vol.]

XI. A very useful solvent of silver has been discovered by Mr. Keir of Birmingham. It is formed by dissolving one part of nitre in about eight or ten parts by weight of concentrated sulphuric acid. This compound (which may be called *nitro-sulphuric acid*) when heated to between 100° and 200° Fahrenheit, dissolves one fifth or one sixth its weight of silver, with an extrication of nitrous gas; and leaves, untouched, any copper, gold, lead, or iron, with which the silver may be combined. Hence it is a most useful agent in extracting silver from old plated goods. The silver may be recovered from the solution by adding muriate of soda, which forms muriate of silver; and this may be decomposed by carbonate of soda, in the way which has already been described.

XII. Silver is acted on by sulphurets of alkalis, and by sulphuretted hydrogen gas. Both these substances blacken silver when exposed to their operation; and the common tarnishing of silver by the atmosphere has been traced to a similar cause.

XIII. Silver is capable of being united with most other metals. When alloyed with copper, in the proportion of one part to twelve, it constitutes the *standard silver* of this country. This combination, though its colour differs but little from that of pure silver, is much harder, and better adapted for the purpose of coin, and of domestic implements.

SECTION IV.

Mercury.

I. MERCURY, or quicksilver, is the only one of the metals that retains a fluid form at the ordinary temperature of the atmosphere.

II. When its temperature is reduced to about 39° or 40° below zero of Fahrenheit, it assumes a solid form. This is a degree of cold, however, that occurs only in high northern latitudes: and in this country quicksilver can only be exhibited in a solid state

by means of artificial mixtures. By congelation it acquires an increase of its specific gravity ; and, therefore, unlike other metals, the congealed portion sinks to the bottom of a fluid mass of mercury. Its specific gravity, at 47° above 0 of Fahrenheit, being 13.545, it was found increased by congelation, in an experiment of Mr. Biddle, to 15.612, or about one seventh.

III. At about 660° of Fahrenheit (656° according to Creighton) mercury boils, and is changed into vapour. Hence it may be driven over by distillation, and may thus be purified, though not accurately, from the admixture of other metals. When its temperature is considerably increased above this point, the vapour acquires great expansive force, and the power of bursting the strongest vessels.

IV. Mercury is not oxidized, when pure, at the ordinary temperature of the atmosphere ; but preserves the lustre of its surface unchanged for a considerable time. There are several methods, however, by which it may be brought to combine with oxygen.

(a) Mercury is oxidized by long continued agitation in a bottle half filled with atmospherical air, and is converted into a black powder, to which Boerhaave gave the name of *ethiops per se*. When this oxide is distilled in a glass retort, oxygen gas is evolved ; or if a moderate heat be long continued, it acquires a redish colour, and a still farther dose of oxygen. The black oxide consists, according to Fourcroy, of 100 parts of metal united with 4 of oxygen.

(b) Another oxide of mercury is obtained by exposing the fluid metal, for several days, to nearly its boiling temperature, in a flat glass vessel, into which air is freely admitted. After a sufficient length of time, small flaky crystals form on its surface, of a redish-brown or flea colour. This brown oxide was formerly called *precipitate per se*. When distilled alone in a glass retort, it yields oxygen gas, and returns to a metallic state. It is composed, according to Lavoisier, of 92 *per cent.* mercury, and 8 oxygen, or according to Fourcroy and Thenard, of 100 metal and 8 of oxygen.

V. Mercury is dissolved by hot and concentrated sulphuric acid. Two parts of sulphuric acid and one of mercury are the proportions generally used ; and as strong sulphuric acid acts but little on iron, the combination may be made in an iron vessel. Part of the redundant acid may be expelled by heat ; but still the salt retains a considerable excess of acid, and may be called su-

per-sulphate of mercury. It is very difficult of solution, requiring 155 parts of cold or 33 of boiling water. By repeated washings with cold water, the whole excess of acid may be removed, and the salt is rendered much more insoluble.

When the super-sulphate is heated for some time, at a temperature exceeding that of boiling water, it loses still more acid, and is changed into a hard grey mass. When this is removed from the fire, and boiling water poured upon it, a lemon yellow coloured powder is formed called *Turbith Mineral.* This substance requires for solution 2000 parts of water. One hundred parts consist of 10 sulphuric acid, 76 mercury, 11 oxygen, and 3 water.

VI. The nitric acid dissolves mercury, both with and without the assistance of heat. At the common temperature, but little nitrous gas is evolved by the action of mercury on nitric acid; and the acid becomes slowly saturated. The solution is very ponderous and colourless; and yields, by evaporation, large transparent crystals. The solution does not become milky when mingled with water. Pure fixed alkalis give a yellowish white precipitate; and ammonia a greyish black one.

But if heat be used, a brisk effervescence arises, occasioned by the escape of nitrous gas, and a solution is obtained, in which the metal is more highly oxidated, and the acid is in less proportion. When this solution is poured into cold water, a yellowish white sediment is formed; or, if into boiling water, an orange coloured one. Both precipitates consist of nitric acid, with a great excess of oxide, forming an insoluble *sub-nitrate of mercury.*

If the last mentioned solution be boiled with a fresh quantity of mercury, the newly added metal is taken up, without any discharge of nitrous gas, the metal becoming oxidized at the expense of that already dissolved.

When the nitrate of mercury is exposed to a heat gradually raised to 600° or upwards, it is deprived of water and of most of its acid, and reduced to an oxide, which has the form of brilliant red scales. This substance, commonly called *red precipitate,* is termed more properly the *nitrous oxide of mercury.*

VII. Mercury is the basis of a new fulminating compound discovered by Mr. E. Howard. To prepare this powder, 100 grains (or a greater proportional quantity not exceeding 500) are to be dissolved, with heat, in a measured ounce and half of nitric acid. The solution being poured cold upon two measured ounces of alcohol, previously introduced into any convenient glass vessel, a

moderate heat is to be applied till effervescence is excited. A white fume then begins to undulate on the surface of the liquor, and the powder will be gradually precipitated on the cessation of action and re-action. The precipitate is to be immediately collected on a filter, well washed with distilled water, and cautiously dried in a heat not exceeding that of a water-bath. The immediate washing of the powder is material, because it is liable to the re-action of the nitric acid ; and while any of that acid adheres to it, it is very subject to be decomposed by the action of light. From 100 grains of mercury, about 120 or 130 of the powder are obtained. (See Philosophical Transactions, 1800, page 214.) This powder has the property of detonating loudly in a gentle heat, or by light friction.

The following fact, respecting the fulminating mercury, is stated by Mr. Accum. Four ounces of this substance were placed, still wet, on a chalkstone, and left in this situation, unobserved, for three months. The product was found converted into a brilliant black powder. On attempting to collect it into a heap, and to separate it from the paper which had been interposed, a globule of running mercury was seen. On introducing the powder into a bottle, and shaking it, heat was evolved, and the whole reduced to the metallic state. (Nicholson's Journal, 8vo. i. 299.)

VIII. Mercury is not dissolved by muriatic acid, but may be brought into union with this acid by double elective affinity. Thus when sulphate of mercury and muriate of soda, both well dried, are mixed and exposed to heat, a combination of oxide of mercury and muriatic acid is obtained by sublimation. This compound is the *corrosive sublimate* of the shops. The same components, with a still farther addition of mercury, constitute an insoluble substance called *calomel.*

The corrosive muriate requires 16 or 20 times its weight of water for solution ; but is soluble in about $\frac{3}{8}$ths its weight of alcohol. Its solution in water is decomposed by all the fixed alkalis and alkaline salts, which throw down at first an orange, and afterwards a brick red precipitate. One hundred parts are composed, according to Mr. Chenevix, of

$$\left. \begin{array}{l} \text{Mercury } 69.7 \\ \text{Oxygen } 12.3 \end{array} \right\} 82 \text{ oxide of mercury}$$

$$18 \text{ acid}$$

$$\overline{}$$

$$100$$

Calomel, or the sub-muriate, is formed by grinding the muriate with about half its weight of metallic quicksilver, and then repeatedly subliming the mixture. As the new compound is nearly insoluble, it may be freed from any remains of the corrosive muriate by washing with water. It consists, according to the testimony of the same author, (Philosophical Transactions, 1802,) of

Mercury 79 ⎱ 88.5 oxide of mercury
Oxygen   9.5 ⎰

. 11.5 acid

——

100

In calomel, then, the oxide of mercury contains about 10 *per cent.* of oxygen, and in the corrosive muriate 15 *per cent.* This determination, however, differs very considerably from that of Fourcroy and Thenard, who have given the following comparative view of the composition of corrosive sublimate and calomel.

Calomel - - ⎰ 100   mercury
            ⎱ 4.16 oxygen
            ⎰ 13.97 acid

Corrosive muriate ⎰ 100   mercury
              ⎱ 8.21 oxygen
              ⎰ 27.39 acid

IX. The oxides of mercury are all reduced by heat alone, without the addition of any combustible substance, and afford oxygen gas.

X. Mercury dissolves gold, silver, tin, and many other metals; and if these be combined with it in sufficient quantity, the mercury loses its fluidity, and forms an amalgam. A solid amalgam of lead, and another of bismuth, on admixture together, have the singular property of instantly becoming fluid. The extraordinary powers of the base of ammonia in amalgamating with mercury, have already been described in speaking of that alkali.

By combination with mercury, metals that are not easily oxidized, acquire a facility of entering into union with oxygen. Thus gold and silver, when combined with mercury, are oxidized by agitation in contact with air. This fact furnishes a striking illustration of the effect of overcoming the aggregative affinity of bodies, in promoting chemical union.

XI. By combination with sulphur, mercury affords two distinct compounds. By long continued trituration, these two bodies unite, and form a black sulphuret. When united together by fu-

sion, and afterwards sublimed, they constitute a red sulphuret call-
ed cinnabar, which, when powdered, affords the common pigment
vermilion. The process used by the Dutch, who have long been
celebrated for the preparation of cinnabar, is described in the
fourth volume of the *Annales de Chimie*, or in Aikin's Dictionary,
vol. ii. This compound also may be obtained by mixing concen-
trated solutions of muriate of mercury and hydro-sulphuret of am-
monia. A brownish muddy precipitate is obtained, which, when
left undisturbed, turns yellow in three or four days, then orange,
and finally acquires a beautiful cinnabar colour. (Nicholson's
Journal, 8vo. 1. 299.)

SECTION V.

Rhodium and Palladium.

THE discovery of these two metals we owe to the ingenuity of
Dr. Wollaston, who separated them from the ore of platina, by the
following process.

I. RHODIUM. When a solution of the ore of platina in nitro-
muriatic acid has been precipitated, as far as possible, by muriate
of ammonia (see sect. 3,) it still retains a considerable degree of
colour, varying with the strength and proportion of the acids that
have been employed in effecting the solution. Beside iron, and a
portion of the ammonia-muriate of platina, it contains, also, other
metals in very small proportion.

1. Let a cylinder, or thin plate of zinc, or iron, be immersed in
the solution. It will separate all the metals that are present in the
state of a black powder. Wash the precipitate (without drying it)
with very dilute nitric acid, assisted by a gentle heat, which will
dissolve the copper and lead. Digest the remainder in dilute ni-
tro-muriatic acid ; and to the solution, when completed, add a
portion of muriate of soda, equivalent in weight to about one fif-
tieth the ore of platina employed. Evaporate by a gentle heat.
The dry mass contains the soda-muriates of platina, palladium and
rhodium ; the two former of which may be separated by alcohol,
and the salt of rhodium will remain. From its solution the rho-
dium may be precipitated by zinc, which throws down a black pow-
der, amounting, in weight, to four grains from 4000 of the ore.

2. When exposed to heat, the powder continues black ; with
borax it acquires a white metallic lustre, but appears infusible by
any degree of heat. It is rendered fusible, however, by arsenic,

and also by sulphur; both of which may be expelled by a continued heat; but the metallic button, thus obtained, is not malleable.

3. The specific gravity of rhodium, as near as it could be taken, was 11.

4. Rhodium unites readily with all the metals that have been tried, excepting mercury. It does not discolour gold, when alloyed with it.

5. When an alloy of silver or gold with rhodium is digested in nitric or nitro-muriatic acid, the rhodium remains untouched; but when alloyed with three times its weight of bismuth, copper, or lead, each of these alloys may be dissolved completely, in a mixture, by measure, of two parts muriatic acid with one of nitric. The lead appears preferable, as it is reduced, by evaporation, to an insoluble muriate. The muriate of rhodium then exhibits the rose colour, from which the name of the metal has been derived. It is soluble in alcohol.

6. Rhodium is not precipitated from its solution by prussiate of potash, nor by muriate of ammonia, nor by hydro-sulphuret of ammonia. The carbonated alkalis produce no change; but the pure alkalis precipitate a yellow oxide, soluble in all acids that have been tried.

II. PALLADIUM. 1. The alcoholic solution (I. 1.) contains the soda-muriates of palladium and platina. The latter metal may be precipitated by muriate of ammonia; and from the remaining liquid palladium may be obtained, by the addition of prussiate of potash, which occasions a sediment, at first of a deep orange colour, and changing afterwards to a dirty bottle-green, owing, probably, to the presence of iron. The precipitate is to be ignited, and purified from iron, by cupellation with borax.

2. A more simple method of obtaining palladium has since been announced by its discoverer.* To a solution of the ore of platina in nitro-muriatic acid, neutralized by evaporating the redundant acid, or by adding an alkali, and either before or after the separation of the platina by muriate of ammonia, let prussiate of mercury be added. In a short time the liquid becomes yellow, and a flocculent precipitate is gradually formed of a pale yellowish white colour, which is the prussiate of palladium. This, on being heated, yields the metal in a pure state, in the proportion of four tenths or five tenths of a grain from every hundred grains of the ore.

On examining some ore of platina, brought from the gold mines

* Phil. Mag. xxii. 272, or Phil. Trans. 1805.

of Brazil, Dr. Wollaston has lately discovered in it small frag-
ments of *native palladium*, which appear to be free from admixture
with every other metal, except a very minute portion of iridium.
These fragments differ from the grains of platina, in being formed
of fibres, which are in some degree divergent from one extremity.
This external character Dr. Wollaston deems sufficient for dis-
tinguishing the metal in situations, where recourse cannot be had
to experiment. (Philosophical Transactions, 1809.)

Those who may wish to examine the properties of palladium,
may now procure it in a metallic state at Messrs. Knights', Foster-
lane, London.

3. The following are the properties of palladium :

(*a*) Its colour resembles that of platina, except that it is of a
duller white. It is malleable and ductile. Its specific gravity
varies from 10.972 to 11.482. Its power of conducting caloric is
nearly equal to that of platina, which it rather surpasses in expan-
sion by heat.

(*b*) Exposed in an open vessel, to a greater degree of heat than
is required to melt gold, no oxidizement ensues ; and no degree
of fusion takes place. On increasing the fire considerably, a melt-
ed button is obtained, and the specific gravity is increased to
11.871. The metal, in this state, has a greyish white colour. Its
hardness exceeds that of wrought iron. By the file it acquires
the brilliancy of platina ; and is malleable to a great degree.

(*c*) Palladium readily combines with sulphur. The compound
is whiter than the separate metal, and is very brittle.

(*d*) It unites with potash by fusion, and also with soda, but less
remarkably. Ammonia, allowed to stand over it for some days,
acquires a blueish tinge, and holds, in solution, a small portion of
oxide of palladium.

(*e*) Sulphuric acid, boiled with palladium, acquires a beautiful
blue colour, and dissolves a portion of the metal. The action of
this acid, however, is not powerful ; and it cannot be considered
as a fit solvent for palladium.

(*f*) Nitric acid acts with much greater violence on palladium.
It oxidizes the metal with somewhat more difficulty than silver ;
and, by dissolving the oxide, forms a very beautiful red solution.
During this process no nitrous gas is disengaged. Nitrous acid
has even a more rapid action on palladium.

(*g*) Muriatic acid, by being boiled on palladium, acts upon it,
and acquires a beautiful red colour.

(*h*) But the true solvent of palladium is nitro-muriatic acid, which acts upon the metal with great violence, and yields a beautiful red solution.

(*i*) From all these acid solutions of palladium, a precipitate may be produced by alkalis and earths. These precipitates are mostly of a fine orange colour; are partly dissolved by some of the alkalis; and that occasioned by ammonia, when thus re-dissolved, has a greenish blue colour. Sulphate, nitrate, and muriate of potash, produce an orange precipitate in the salts of palladium, as in those of platina; but the precipitates from nitrate of palladium have generally a deeper shade of orange. All the metals, except gold, platina, and silver, cause very copious precipitates in solutions of palladium. Recent muriate of tin produces a dark orange or brown precipitate, from neutralized salts of palladium, and is a very delicate test of this metal. Green sulphate of iron precipitates palladium in a metallic state; and, if the experiment succeed, the precipitate is about equal in weight to the palladium employed. Prussiate of potash causes an olive-coloured precipitate. The prussiate of palladium, separated by a neutral solution of prussiate of mercury, has the property, when heated to about 500° of Fahrenheit, of detonating, with a noise similar to that occasioned by firing an equal quantity of gunpowder. Hydro-sulphurets, and water impregnated with sulphuretted hydrogen gas, occasion a dark brown sediment from solutions of palladium.

(*k*) Palladium readily combines with other metals. It has the property, in common with platina, of destroying the colour of gold, even when in a very small proportion.—Thus one part of platina, or palladium, fused with six of gold, reduces the colour of the gold nearly to that of the white metal employed.

SECTION VI.

Iridium and Osmium.

WHEN the ore of platina has been submitted to the action of nitro-muriatic acid, a part remains undissolved, in the form of a black powder, resembling plumbago. In this substance, Mr. Tennant has lately discovered two new metals. The process, which he employed to separate them, was the following:

I. 1. The powder was fused in a silver crucible with pure soda, and the alkali then washed off with water. It had acquired a deep orange or brownish yellow colour, but much of the powder was-

undissolved. The residue was digested in muriatic acid, and a
dark blue solution obtained, which afterwards became of a dusky
olive green; and, finally, by continuing the heat, of a deep red
colour. By the alternate action of the acid and alkali, the whole
of the powder appeared capable of solution.

2. The alkaline solution contained the oxide of a volatile metal
not yet described; and also a small portion of another metal.
When the solution was kept some weeks, the latter metal separat-
ed spontaneously in thin dark-coloured flakes. The acid solution
contained both metals also; but principally one, which is not al-
tered by muriate of tin; is precipitated of a dark brown colour by
pure alkali; and which exhibits, during solution in muriatic acid,
a striking variety of colours, arising from variations in its degree
of oxigenizement.—From this property Mr. Tennant terms it IRI-
DIUM.

3. In order to obtain muriate of iridium, free from the other
metal, the acid solution (2) was evaporated, and an imperfectly
crystallized mass obtained; but this, dried on blotting-paper, and
again dissolved and evaporated, gave distinct octahedral crystals.
The watery solution of these crystals had a deep red colour, inclining
to orange. With infusion of galls no precipitation ensued; but
the colour almost instantly disappeared. Muriate of tin, carbon-
ate of soda, and prussiate of potash, had the same effect. Pure
ammonia precipitated the oxide, but retained a part, and acquired
a purple colour. All the metals, except gold and platina, precip-
itated iridium of a dark colour from the muriate, which had lost
its colour.

4. Iridium was obtained pure by heating the muriate, which
expelled both the acid and the oxygen. It was of a white colour,
and perfectly infusible. It did not combine with sulphur or arsen-
ic. Lead united with it, but was separated by cupellation. Cop-
per, silver, and gold, were severally found to combine with it, and
it could not be separated from the two latter by cupellation with
lead.—Its other properties remain to be examined.

II. 1. Osmium was procured in the state of an oxide, by sim-
ply distilling the alkaline solution, obtained as already described
(I. 1.) along with any acid. It was even found to escape, in part,
when water was added to the dry alkaline mass remaining in the
crucible; and was manifested by a pungent and peculiar smell,
from which property its name has been derived. The watery so-
lution of oxide of osmium is without colour, having a sweetish

taste, and the strong smell already alluded to. Another mode of obtaining, still more concentrated, the oxide of osmium, is by distilling the original black powder with nitre. A solution of oxide of osmium in water is found in the receiver, of such strength as to give a stain to the skin that cannot be effaced. The most striking test of this oxide is an infusion of galls, which presently becomes of a purple colour, and afterwards changes to a deep vivid blue. With pure ammonia, the solution becomes somewhat yellow; and slightly so with carbonate of soda. With alcohol, or still more quickly with ether, it acquires a dark colour, and, after some time, separates in the form of black films.

2. The oxide of osmium gives up its oxygen to all the metals, excepting gold and platina. When its solution in water is shaken with mercury, the solution loses its smell; and the metal, combining with the mercury, forms an amalgam. From this, much of the redundant mercury may be separated by squeezing it through leather, which retains the amalgam of a firmer consistence. The mercury being distilled off, the osmium remains in its metallic form, of a dark grey or blue colour. By exposure to heat, with access of air, it evaporates with its usual smell; but, if oxidation be effectually prevented, it does not seem in any degree volatile. Being subjected to a strong white heat, in a cavity made in a piece of charcoal, it is not melted, nor does it undergo any change. With gold and silver it forms malleable alloys. These are easily dissolved in nitro-muriatic acid; and by distillation give the oxide of osmium with its usual properties.

3. The pure metallic osmium, which had been previously heated, does not seem to be acted upon by acids; at least no effect is produced by boiling it some time in nitro-muriatic acid. By heating it in a silver cup with alkali, it immediately combines with the alkali, and this compound gives, with water, a yellow solution, similar to that from which it had been procured. From this solution, acids expel the oxide of osmium, having its usual smell, and possessing the property of changing to a vivid blue the infusion of galls.

Besides the black powder from which osmium is obtained, Dr. Wollaston has discovered a separate ore of these two metals, mixed with the grains of crude platina. The specific gravity of this ore is about 19.5, and therefore exceeds that of crude platina itself, which is only 17.7. The grains are about the size of those

of crude platina, but are considerably harder; are not at all malleable; and appear to consist of laminæ, possessing a peculiar lustre.

SECTION VII.

Copper.

COPPER is a metal of a beautiful red colour, and admits of a considerable degree of lustre. Its specific gravity varies with the operations to which it has been subjected. Lewis states it at 8.830; Mr. Hatchett found that of the finest granulated Swedish copper to be 8.895; and Cronstedt states the specific gravity of japan copper at 9.

It has considerable malleability, and may be hammered into very thin leaves. It is, also, very ductile; and may be drawn into wire, which has great tenacity.

At 27° Wedgwood, copper fuses, and by a sufficient increase and continuance of the heat, it evaporates in visible fumes.

I. 1. Copper is oxidized by air. This may be shown by heating one end of a polished bar of copper, which will exhibit various shades of colour, according to the force of the heat.

A plate of copper, exposed for some time to heat, becomes covered with an oxide, which breaks off in scales when the copper is hammered. It is composed of 62 of the black oxide and 38 copper. This oxide, when exposed on a muffle, is farther oxidized, and assumes a deep red hue. Copper is also oxidized by long exposure to a humid atmosphere, and assumes a green colour; but the green oxide holds carbonic acid in combination. These compounds do not return to a metallic state by the mere application of heat; but require, for their reduction, the admixture of inflammable matter.

2. Copper does not decompose water, which may even be transmitted, in vapour, through a red-hot tube of this metal, without decomposition.

3. Copper is susceptible of only two degrees of oxidizement; in its lower stages the compound is red if native, or orange coloured if artificial. When oxidated to the maximum, it is black.

The *black oxide* may be obtained, either by calcining the scales of copper, which have already been alluded to, under a muffle; or by decomposing sulphate of copper by carbonate of potash, and igniting the precipitate; or by the simple ignition of the nitrate of copper. It is composed of

Copper   -   -   80
Oxygen   -   -   20
                    ———
                    100

To prepare the *sub-oxide* Mr. Chenevix recommends the following process. Mix together $57\frac{1}{2}$ parts of black oxide of copper, and 50 parts of metallic copper precipitated from the sulphate on an iron plate. Triturate it in a mortar, and put it with muriatic acid into a phial, which is to be well stopped. The copper and its oxide will be dissolved with heat. When potash is poured into this solution, the oxide of copper is precipitated of an orange colour. This oxide, which attracts oxygen so strongly that it can scarcely be dried without absorbing more, is composed of

Copper   -   -   88.5
Oxygen   -   -   11.5
                    ———
                    100

II. Copper combines with strong sulphuric acid, in a boiling heat, and affords a blue salt, called sulphate of copper. (*a*) Sulphate of copper is a regularly crystallized salt, easily dissolved by water. (*b*) The solution is decomposed by pure and carbonated alkalis. The former, however, re-dissolve the precipitate. Thus, on adding pure liquid ammonia to a solution of sulphate of copper, a precipitate appears, which, on a farther addition of the alkali, is re-dissolved, and affords a beautiful bright blue solution. (*c*) The sulphate of copper is decomposed by iron. In a solution of this salt immerse a polished plate of iron. The iron will soon acquire a covering of copper in a metallic state. (*d*) It gives up its acid on the application of heat, without decomposition; and an oxide of copper remains in the retort. (*e*) It is composed, according to Proust, of

Copper 25.6 ⎱ forming   ⎱ 32
Oxygen   6.4 ⎰ black oxide ⎰
Sulphuric acid   -   -   32
Water   -   -   -   36
                           ———
                           100

The sulphate, strictly speaking, is a super-salt. Proust, also, describes a sub-sulphate, formed by adding potash to the common

sulphate, but not in sufficient quantity to separate the oxide. A green sediment appears, which is the sub-sulphate.

III. Copper exposed to a damp air rusts, and becomes covered with carbonate of copper. The same compound is still more readily produced by adding carbonated alkalis to the solutions of copper. The nitrate of copper, precipitated by carbonate of lime affords an apple green precipitate, called *Verditer*. This substance consists of

Water - - - - - - -	$3\frac{1}{3}$
Carbonic acid - - - -	30
Lime - - - - - -	7
Copper - - - - - -	50
Oxygen - - - - - -	$9\frac{2}{3}$
	———
	100

IV. Copper dissolves readily in diluted nitric acid; and nitrous gas is evolved in great abundance. The salt, resulting from this combination, has the singular property of detonating with tin. When to the solution of this salt, or of any other salt of copper, a solution of potash is added in sufficient quantity, a blue powder is precipitated, consisting of the black oxide of copper combined with water. This substance has been called by Proust hydrate of copper; but, more properly, by Mr. Chenevix, hydro-oxide of copper. When collected on a filtre, and dried at a heat below that of boiling water, it shrinks somewhat like alumine; but still retains its colour. At a higher temperature it is decomposed, its water being dissipated, and the black oxide only remaining, in the proportion of 75 parts from 100. This oxide cannot be brought to combine with water again by merely moistening it.

V. Concentrated and boiling muriatic acid acts on copper; and a green solution is obtained. In this salt the copper is oxidized to its maximum. It is very soluble in water, and generally deliquescent. By careful evaporation and cooling, the salt crystallizes in rhomboidal prismatic parallelopipeds, which are readily soluble both in water and alcohol. It is composed, as Proust has stated, of

Black oxide of copper - - -	40
Muriatic acid - - - -	24
Water - - - - - -	36
	———
	100

The watery solution of muriate of copper forms a kind of sympathetic ink. Characters written with it become yellow by warming, and again disappear when the paper cools.

By digesting a solution of muriate of copper with filings of the metal, it is converted into a submuriate, the fresh portion of copper being oxidized at the expense of what was previously held in solution. The solution of this salt is precipitated by merely pouring it into water. By exposure to air, it acquires oxygen and is converted into the common green muriate. Alkalis throw down an orange precipitate. It consists of

$$\begin{array}{lrl}
\text{Copper} & 65.80 & \left\{ \text{forming} \right. \\
\text{Oxygen} & 8.08 & \left. \text{sub-oxide} \right\} 73.88 \\
\text{Acid} & \text{-}\quad\text{-}\quad\text{-}\quad\text{-} & 26.12
\end{array}$$

——————

100

VI. When corroded by long continued exposure to the fumes of vinegar, copper is converted into verdegris.—The verdegris of commerce consists partly of an acetate, soluble in water, and partly of a sub-acetate. By solution in distilled vinegar and evaporation, it forms regular crystals, which are completely soluble in water.—These, distilled alone, yield concentrated acetic acid, and a combination remains in the retort, containing in 9 parts

4.50 charcoal

78.66 copper

6.84 oxygen

VII. When the muriate of copper is mixed with a solution of prussiate of potash or of lime, a beautiful redish brown precipitate is obtained, which has been recommended by Mr. Hatchett as a pigment. Tincture of galls throws down from all the solutions of copper a dirty yellow precipitate.

VIII. Copper combines with sulphur. When a mixture of three parts of the metal, in the state of fine filings, with one part of sulphur, is melted in a glass tube, at the moment of combination, a brilliant inflammation ensues, exceeding, in brightness, that produced by the fusion of iron and sulphur.

IX. Ammonia readily dissolves the oxides and hydro-oxides of copper. Nothing more is necessary than to digest them together in a phial. The oxide is dissolved, and the solution acquires a beautiful deep blue colour. By evaporation in a very gentle heat, fine blue silky crystals may be obtained.

X. Copper combines readily with most of the metals, and af-

fords several compounds, which are of great use in the common arts of life. *Tutenag* is a white alloy of copper, zinc, and iron. Copper, with about a fourth its weight of lead, forms *pot-metal ;* with about the same proportion of zinc, it composes *brass,* the most useful of all its alloys. Mixtures of zinc and copper form, also, the various compounds of *Tombac, Dutch Gold, Similor, Prince Rupert's Metal, Pinchbeck,* &c. Copper with tin, and sometimes a little zinc, forms *bronze* and *bell-metal,* or *gun-metal.* And when the tin is nearly one third of the alloy, it is beautifully white and takes a high polish. It is then called *speculum-metal.*

SECTION VIII.

Iron.

IRON has a blueish white colour, and admits of a high degree of polish. It is extremely malleable, though it cannot be beat out to the same degree of thinness as gold or silver. It is much more ductile, however, than these metals ; for it may be drawn out into wire as fine as a human hair ; and its tenacity is such that a wire only $\frac{78}{1000}$ths of an inch in diameter is capable of supporting a weight of nearly 550lb. Its specific gravity varies from 7.6 to 7.8.

Iron is one of the most infusible of the metals. Its melting point is about 158° of Wedgwood. Its chemical properties are the following :

I. 1. When exposed to the atmosphere, especially when the air is moist, it slowly combines with oxygen, or, in common language, *rusts.* If the temperature of the metal be raised, this change goes on more rapidly ; and, when made intensely hot, takes place with the appearance of actual combustion. Thus the small fragments, which fly from a bar of iron during forging, undergo a vivid combustion in the atmosphere ; and iron filings, projected upon the blaze of a torch, burn with considerable brilliancy. The oxide, obtained in these ways, is of a black colour, and is still attracted by the magnet. It is composed in 100 parts of

$$
\begin{array}{lcccc}
\text{Iron} & - & - & - & - & 76 \\
\text{Oxygen} & - & - & - & 24 \\
\end{array}
$$

$$\overline{100}$$

The same change is more rapidly produced, when ignited iron is brought into contact with oxygen gas. A vivid combustion

happens, as already described in the chapter on that gas. This black oxide calcined in a low red heat, with free access of air, acquires a farther addition of oxygen, and yields the red oxide, consisting of

<div align="center">

69 iron

31 oxygen

———

100

</div>

2. By contact with water at the temperature of the atmosphere, iron becomes slowly oxidized, and hydrogen gas is evolved. When the steam of water is brought into contact with red-hot iron, the same change is produced with much greater rapidity; the iron is converted into the black oxide; and a large quantity of hydrogen gas is set at liberty, and may be collected by a proper apparatus. The iron is found to have lost all its tenacity, and may be crumbled down into a black powder, to which the name of *finery cinder* was given by Dr. Priestly. In composition, it does not appear to differ from the oxide of iron obtained by the action of atmospheric air, and is strongly magnetic.

II. Iron is not much acted upon by concentrated sulphuric acid; but the diluted acid dissolves it readily with an extrication of hydrogen gas; the oxygen, essential to the solution of the metal being derived, not from the acid, but from the water. From the quantity of hydrogen gas, disengaged during the solution, it has been calculated that the iron does not acquire so much oxygen as exists in the black oxide, which has been already described. And as the solution, when an excess of iron is used, is colourless, and affords, when fresh made, a white precipitate, we may admit, with Thenard, the existence of a white oxide of iron, composed, in 100 parts, of

<div align="center">

$77\frac{1}{2}$ iron

$22\frac{1}{2}$ oxygen

———

100

</div>

The solution of iron in sulphuric acid, when evaporated, forms rhomboidal prismatic crystals, which have a beautiful green colour. They have a strong styptic taste, and redden vegetable blue colours; are soluble in about two parts of cold, and $\frac{3}{4}$ths their weight of boiling water; but are insoluble in alcohol. According to Kirwan, they are composed of 26 acid, 28 black oxide, and 46 water. The solution, when exposed to the air, becomes yel-

low, and deposites a powder, which is an oxide of iron with a far-ther quantity of oxygen. By distillation, the crystals are decompos-ed, and yield a strong fuming acid, called *glacial sulphuric* acid.

When the sulphate of iron is decomposed by alkalis, the colour of the precipitate is green, though that of the oxide is black. This appears to be owing to the chemical combination of a quan-tity of water with the oxide, constituting a *hydrat* or *hydro-oxide.*

To the salt which has been just described, the appellation of sulphate of iron is strictly due. But sulphuric acid is susceptible, also, of union with the oxide containing a larger proportion of ox-ygen; and in this state it has received the name (not strictly prop-er) of *oxy-sulphate.* It may be formed, either by long exposure to the air of a solution of the sulphate, or by adding to it a small proportion of nitric acid, or by passing through it a stream of oxy-muriatic acid gas.

This salt has a yellowish red colour, and is not crystallizable; but, when evaporated to dryness, attracts moisture from the air. It is soluble in alcohol, and by this agent may be separated from the green sulphate.

The oxy-sulphate may be changed into the common sulphate by a variety of substances, which are capable of depriving the ox-ide of part of its oxygen. This may be effected by digesting iron filings with the solution, or by passing through it a stream of sul-phuretted hydrogen gas. The muriate of tin, also, in which the metal is at the minimum of oxidizement, has a similar action.

III. Nitric acid, in its concentrated state, scarcely acts upon iron, but, when diluted with a small quantity of water, it dissolves iron with great vehemence; and with the extrication of a large quantity of nitrous gas. The solution, at first, is a deep green, but when nearly saturated assumes a red colour. It is not crys-tallizable, but, when evaporated, forms a deliquescent mass.

Nitric acid is not capable of dissolving iron very much oxidat-ed; and this acid may be advantageously used to bring the metal to its maximum of oxidation. By repeatedly boiling iron to dry-ness with nitric acid, we obtain the red peroxide of that metal, which has been already described.

The nitrate of iron, it has been shown by Mr. Davy, may exist in two different states, the green nitrate in which the oxide is at the minimum of oxidation, and the red, in which it is at the maxi-mum.

IV. Muriatic acid dissolves iron and its oxides with great ease;

and affords two distinct salts, differing from each other according to the state of oxidation of the metal. The muriate containing the black oxide is green, and that containing the oxide at the maximum red. Both these salts are deliquescent, and cannot be brought to crystallize.

V. Iron may be united, in the way of double elective affinity, with the prussic acid.* Thus, when triple prussiate of potash and iron and sulphate of iron, both in solution, are mixed together, the prussic acid and oxide of iron quit their former combinations and unite together. The beautiful blue precipitate is prussiate of iron.

(a) Prussiate of iron is nearly insoluble in water.

(b) It is not soluble in acids.

(c) It is decomposed by a red-heat, the prussic acid being destroyed, and an oxide of iron remaining.

(d) It is decomposed by pure alkalis and earths, which abstract the prussic acid, and leave an oxide of iron. Thus, when pure potash is digested with prussiate of iron, its beautiful blue colour disappears, and we obtain a compound of potash and prussic acid ; still retaining, however, a considerable proportion of oxide of iron, which varies from 24 to 30 per cent. It is in fact, therefore, a triple prussiate of potash and iron ; but as no combination of the two first is known, it may be termed, for the sake of brevity prussiate of potash.

In Nicholson's Journal (4to. iv. 30. 171,) I have given an improved process for preparing the triple prussiate of potash. The following, after trying various modes of preparation, I find to afford the purest test.

1. To a solution of potash, deprived of its carbonic acid by quicklime, and heated nearly to the boiling point, in an iron kettle, add, by degrees, powdered Prussian blue till its colour ceases to be discharged. Filter the liquor, and wash the sediment with water till it ceases to extract any thing ; let the washings be all mixed together, and placed in an earthen dish in a sand-heat.—When the solution has become hot, add a little diluted sulphuric acid, and continue the heat for about an hour. A copious precipitate will be formed of Prussian blue.—Let this be separated by filtration, and assay a small quantity of the filtered liquor in a wine glass, with a little dilute sulphuric acid. If an abundant produc-

* This acid will be mentioned hereafter.

tion of Prussian blue should still take place, fresh sulphuric acid must be added to the whole liquor, which must again, with this addition, be exposed to heat. These filtrations and additions of sulphuric acid must be repeated as long as any considerable quantity of Prussian blue is produced ; but when this ceases, the liquor may finally be passed through a filter.

2. Prepare a solution of sulphate of copper in about four or six times its weight of warm water, and into the solution (1) pour this, as long as a redish brown or copper coloured sediment continues to appear. Wash this sediment, which is a prussiate of copper, with repeated affusions of warm water ; and, when these come off colourless, lay the precipitate on a linen filter to drain, after which it may be dried on a chalk stone.

3. Powder the precipitate, when dry, and add it by degrees to a solution of pure potash, prepared as described, vol. i. page 173. The prussic acid will leave the oxide of copper and pass to the alkali, forming a prussiate of potash as free from iron as it can be obtained.

4. But as the salt still contains sulphate of potash, a portion of this may be separated by gentle evaporation, the sulphate crystallizing first. To the remaining liquid, add a solution of barytes in warm water (vol. i. page 195) as long as a white precipitate ensues, observing not to add more after its cessation. The solution of prussiate is now free, in a great measure, from iron, and entirely from sulphates ; and, by gentle evaporation, will form, on cooling, beautiful crystals. A solution of these in cold water affords the purest prussiate of potash that can be prepared.

For the vegetable alkali, either soda or ammonia may be substituted in the above process, if they be preferred. If a sufficient quantity of pure barytes cannot be had, the sulphate may be precipitated by acetate of barytes. The acetate of potash, thus formed, not being a crystallizable salt, remains in the mother liquor.

(e) When the prussiate of potash is mixed with sulphate of iron, in which the metal is as little oxidized as possible, the prussiate of iron that is formed is of a white colour, but gradually becomes blue, as the iron, by exposure to air, acquires more oxygen. (See Proust's memoir, in Nicholson's Journal.)

(f) The effect of a sympathetic ink may be obtained, by writing with a pen dipped in a very dilute solution of prussiate of potash. No characters will appear till the paper is moistened with sulphate of iron, when letters of a Prussian blue colour will be apparent.

The experiment may be reversed, by writing with sulphate of iron, and rendering the characters legible by prussiate of potash.

(*g*) The prussiate of potash decomposes all metallic solutions, excepting those of gold, platina, iridium, osmium, rhodium, tellurium, and antimony. (See Proust, Philosophical Magazine, xxx. 42.)

VI. When sulphate of iron is mixed with an infusion of galls, we obtain a black solution, which is a new combination of oxide of iron, with the gallic acid and tan. Both the gallate and tannate of iron are, therefore, essential constituents of inks; the other ingredients of which are chiefly added with the view of keeping these suspended.

In order that the iron may unite with the gallic acid and tan, it must be combined with the sulphuric acid in the state of red oxide; for the less oxidized iron, in the green salt, does not form a black compound with these substances. Iron filings, however, dissolve in an infusion of galls with an extrication of hydrogen gas; but the compound is not black till after exposure to air, which oxidizes the iron still farther. This solution, with a sufficient quantity of gum, forms an excellent ink.

On the same principle may be explained the effect of metallic iron in destroying the colour of ink. When ink is digested with iron filings, and frequently shaken, its colour decays; and it also becomes colourless after having a stream of sulphuretted hydrogen gas passed through it. In both these cases the oxide of iron is partly deoxidized. Characters written with ink, after this treatment, are at first illegible, but become black as the iron acquires oxygen from the air.

(*a*) Write upon paper with an infusion of galls. The characters will not be legible till a solution of sulphate of iron is applied. This experiment may be reversed like the preceding one (V. *f.*)

(*b*) The combination of iron, forming ink, is destroyed by pure and carbonated alkalis. Apply a solution of alkali to characters written with common ink, the blackness will disappear, and the characters will become brown, an oxide of iron only remaining on the paper.

Alkalis, added cautiously to liquid ink, precipitate the black combination, but an excess re-dissolves the precipitate.

(*c*) Characters, which have been thus defaced may again be rendered legible by an infusion of galls.

(*d*) Ink is decomposed by most acids, which separate the oxide of iron from the gallic acid in consequence of a stronger affinity. Hence ink-stains are removed by dilute muriatic acid, and by some vegetable acids. Hence, also, if to a saturated solution of sulphate of iron there be added an excess of acid, the precipitate no longer appears on adding infusion of galls.

When a mixture of ink is heated with nitric acid, the yellow oxalate of iron is formed, and is precipitated on adding pure ammonia.

(*e*) Ink is decomposed by age, partly in consequence of the farther oxidation of the iron, and partly, perhaps, in consequence of the decay, or escape, of the acid of galls. Hence ink-stains degenerate into iron-moulds, and these last are immediately produced on an inked spot of linen when washed with soap, because the alkali of the soap abstracts the gallic acid, and leaves only an oxide of iron.

(*f*) Ink is decomposed by oxigenized muriatic acid, which destroys the gallic acid, and the resulting muriatic acid dissolves the oxide of iron.

As all writing inks, into the composition of which iron enters, are liable to decay by time, and to be destroyed by various agents, an ink has been proposed by Mr. Close, the basis of which is similar to that of printing ink.—Take oil of lavender 200 grains, gum copal, in powder, 25 grains, and lamp-black from $2\frac{1}{2}$ to 3 grains. With the aid of a gentle heat dissolve the copal in the oil of lavender, in a small phial, and then mix the lamp-black with the solution, on a marble slab, or other smooth surface. After a repose of some hours, the ink must be shaken before use, or stirred with an iron wire, and, if too thick, must be diluted with a little oil of lavender. (See Nicholson's Journal, 8vo. ii. 145.) This ink I have found extremely useful in writing labels for bottles which contain acids, or which are exposed to acid fumes in a laboratory.

VII. The phosphoric acid acts with but little energy upon iron ; though a native compound of this acid and iron imparts, to some varieties of the metal, the singular property of being very brittle when cold, or, as it is called, *cold-short.*

The phosphate of iron is almost insoluble in water. It is best prepared by mixing the solutions of sulphate of iron and phosphate of soda. A white precipitate is formed, which is soluble in many of the acids, and precipitated without change by ammonia.

The *oxy-phosphate* of iron is, also, an insoluble salt. It may

be formed by mingling the solutions of phosphate of soda and oxy-
sulphate of iron. Its colour is a light blue. Both these prepara-
tions have lately derived some importance, from being recommend-
ed as remedies of cancer.

VIII. The succinic acid composes with iron a brown mass, in-
soluble in water. The combination is best effected by double de-
composition, and especially by the addition of a solution of succin-
ate of ammonia to the salts of iron. A loose brown red precipitate
of succinate of iron falls down. This precipitate Klaproth expos-
es to heat, first by itself, and afterwards mixed with a small quan-
tity of linseed oil. The first operation destroys the acid, and the
second reduces the metal to the state of black oxide. Now as the
black oxide contains, in 100 parts, 76 of metallic iron, the precipi-
tation of a solution, by succinate of ammonia, affords a ready meth-
od of estimating the quantity of iron in any solution of that metal,
or in any of its salts.

IX. The acetic acid, or even common vinegar, acts slowly up-
on iron, and forms a solution, which is of great use in dying and
calico-printing. The acetite of iron may, also, be obtained by
double decomposition, if we mingle the solutions of acetite of lime
or of lead with one of sulphate of iron. It may be formed, also, by
boiling acetite of lead with metallic iron, which precipitates the
lead in a metallic state.

This combination of iron with acetous acid may exist, like its
other salts, in two different states. In the one, the oxide is at the
minimum, and in the other at the maximum of oxidation. It is
the latter salt only, which is adapted to the use of the dyer and
calico-printer.

X. Iron is dissolved by water impregnated with carbonic acid.
A few iron filings, when added to a bottle of aërated water, and oc-
casionally shaken up, impregnate the water with this metal. The
solution is decomposed by boiling, and in a less degree by expos-
ure to air.

XI. Iron combines with sulphur, and affords compounds, the
characters of which vary greatly according to the proportions of
their components. (a) A paste of iron filings, sulphur, and wa-
ter, if in sufficient quantity, will burst, after some time, into flame.
(b) A mixture of one part of iron filings and three parts of sulphur,
accurately mixed, and melted in a glass tube, at the moment of
union exhibits a brilliant combustion. (See note 35 at the end of
this vol.) Another method of effecting the combination of iron

and sulphur is to take a bar of the metal, while of a glowing heat, from a smith's forge, and to rub it with a roll of sulphur. The compound of iron and sulphur falls down in drops, and may be preserved in a phial. Of all the compounds of sulphur, this is best adapted for affording pure sulphuretted hydrogen gas with diluted acids. (c) The sulphuret of iron, when moistened, rapidly decomposes oxygen gas. (d) When diluted sulphuric or muriatic acid is poured on it, we obtain sulphuretted hydrogen gas.

In the perfect sulphuret, made artificially by fusion, as well as in the native sulphuret, iron (it has been shown by Proust and Mr. Hatchett) is in the metallic state, or very nearly so. Two compounds, also, have been proved to exist, the one with a larger, the other with a smaller proportion of sulphur. The former may be called the *super-sulphuret ;* and the latter, which is distinguished by the property of being magnetic, the *sulphuret.* The super-sulphuret is not magnetic ; is nearly insoluble in diluted sulphuric and muriatic acids; and gives no sulphuretted hydrogen gas. But the sulphuret is readily soluble, obeys the magnet, and gives abundance of sulphuretted hydrogen with dilute acids. One hundred parts of the sulphuret consist of

> 62.5 iron
> 37.5 sulphur
> _____
> 100

And 100 parts of the super-sulphuret are composed of

> 52.64 iron
> 47.36 sulphur
> _____
> 100

XII. Iron combines with carbon in various proportions ; and the variety of proportion occasions very different properties in the compound. On these varieties, and the occasional combination of a small proportion of oxygen, depend the qualities of the different kinds of iron used in the arts, as cast-iron, steel, &c. &c. The quantity of carbon, in the sub-carburets of iron, may be determined by solution in sulphurous acid, which dissolves the iron and sulphur, and has no action on carbon. An ingenious mode of analysis, employed by Mr. Mushet, consists in ascertaining the quantity of litharge, which a given quantity of the iron under examination is capable of reducing, by fusion, to a metallic state.

There can scarcely be a more striking example of essential

differences in external and physical characters being produced by slight differences of chemical composition; for steel owes its properties to not more than about $\frac{1}{200}$th its weight of plumbago.

Cast or *crude iron*, besides casual impurities, contains oxygen, carbon, and vitrifiable earth; and its differences depend on the various proportion of carbon, which is greatest in the black, and least in the white, variety of iron. By the process of refining, the carbon and oxygen unite together, and escape in the form of carbonic oxide; while another part of the oxide of iron unites to the earthy matter, and rises to the surface in the form of a dense slag. After this process, it forms *malleable* or *bar-iron*, which may be considered as iron still holding some oxygen and carbon in combination.* If the bar-iron be long and slowly heated, in contact with charcoal, it loses oxygen and acquires carbon. A small proportion only of the latter is not capable of depriving it entirely of the properties of malleable iron, for though it becomes a good deal harder, yet it may still be welded. By union with a still farther quantity of carbon, it loses altogether the property of welding; is rendered harder and more compact; and forms the fine *cast steel.* Steel, therefore, though like cast iron it contains carbon, yet differs from it essentially in being destitute of oxygen and earth.

Another combination of iron and carbon, which is a true carburet of iron, is the substance called *plumbago*, or black-lead, used in fabricating pencils, and in covering iron to prevent rust. By exposure to the combined action of heat and air, the carbon is burned off, and the oxide of iron remains. When mingled also with powdered nitrate of potash, and thrown into a crucible, a deflagration ensues; and an oxide of iron, equal to about one tenth the weight of the plumbago, may be obtained by washing off the alkali of the nitre. From recent experiments of Messrs. Allen and Pepys, it appears that pure plumbago, when burnt in oxygen gas, leaves a residue of oxide of iron amounting only to about 5 *per cent.;* and that it gives very nearly the same quantity of carbonic acid, by combustion, as the diamond and charcoal. When intensely heated in a Toricellian vacuum by a Voltaic battery, Mr. Davy found that its characters remained wholly unaltered. Neither could any evidence of its containing oxygen be derived from the action of potassium. (Philosophical Transactions, 1809.)

* It has been lately suggested by Hassenfratz, and with some probability, that iron, which is manufactured with wood charcoal, owes much of its superiority to combination with potassium. (Nicholson's Journal, xxv. 51.)

SECTION IX.

Nickel.

I. To obtain nickel in a state of purity, the metal usually sold under that name may be dissolved in diluted nitric acid; the solution, evaporated to dryness; and the dry mass be again, for three or four times, alternately dissolved in the acid, and boiled to dryness. After the last evaporation, the mass may be dissolved in a solution of pure ammonia; which has been proved, by its occasioning no precipitation from muriate of lime, to contain no carbonic acid. The solution is next to be evaporated to dryness; and, after being well mixed with twice or thrice its weight of black flux, is to be exposed to a violent heat in a crucible for half or three quarters of an hour.

Another process for purifying nickel is given by Richter, in Nicholson's Journal, xii. 75. The properties of this metal in a state of purity, he describes as follows:

1. Its colour is intermediate between those of silver and tin.

2. It is not oxidized by exposure to the air.

3. It is perfectly malleable; may be forged into bars when hot; and hammered into plates when cold. When cast, its specific gravity is 8.279; and, when forged, 8.666.

4. In infusibility it appears to equal manganese.

5. Nickel appears to be susceptible of two different states of oxidation. By long exposure to a strong heat, with free access of air, it is converted into a dark brown oxide, which is still magnetic. When precipitated from its solutions by alkalis, and moderately ignited, it becomes of an ash-grey colour with a slight tinge of blue or green, and in this state contains, according to Klaproth, 66 metal, and 34 oxygen. By farther ignition, it becomes blackish grey, and then consists, as stated by Richter, of 78 metal and 22 oxygen. All the salts of nickel, when thrown into boiling potash, afford a green precipitate, which is the *hydrate* of nickel. (Proust, Philosophical Magazine, xxx.) In a sufficiently high temperature, its oxides are reducible without addition; nor is it more tarnished by a strong heat than gold, silver, or platina. It ranks, therefore, among the noble or perfect metals.

6. The magnet not only acts on nickel, with a force little inferior to what it exerts on iron; but nickel itself acquires polarity in the usual modes.

7. The sulphuric and muriatic acids have little action on nickel. Its appropriate solvents are the nitric and nitro-muriatic acids. The nitric solution has a beautiful grass-green colour. Carbonate of potash throws down an apple-green precipitate, which assumes a dark grey colour when heated.

8. When pure ammonia is added to nitrate of nickel, a precipitate is formed, resembling that which is separated by ammonia from a solution of copper, but not of so deep a hue. This colour changes, in an hour or two, to an amethyst red, and to a violet; which colours are converted to apple-green by an acid, and again to blue and violet by ammonia. If the precipitate retains its blue colour, the presence of copper is indicated. (See Richter, in Nicholson's Journal, xii.)

9. Solutions of all the salts of nickel are decomposed by alkaline hydro-sulphurets, with which they form black precipitates; but sulphuretted hydrogen has no effect on them.

10. From the solutions of nickel, prussiate of potash throws down a sea-green precipitate. According to Bergman, 250 parts of this contain 100 of metallic nickel. This statement, however, differs considerably from Klaproth's, according to whom 100 grains of nickel, after solution in sulphuric acid, give a precipitate by prussiate of potash, which, after being ignited, weighs 300 grains.

11. Tincture of galls produces no change in these solutions.

12. The solutions of nickel do not deposite the metal either on polished iron or zinc. (See Klaproth's Analytical Essays, vol. i. page 433.) All that takes place by the action of zinc is the separation of a mud-coloured precipitate, consisting, for the most part, of arsenic and iron, with which nickel generally abounds. Hence the green colour of the solution is greatly improved by this metal.

13. Nickel may be alloyed with most of the metals, but the compounds have no particularly interesting qualities. An alloy of iron and nickel has been found in all the meteoric stones that have hitherto been analysed, however remote from each other the parts of the world in which they have fallen. (See note 36 at the end of this vol.)

SECTION X.

Tin.

THE properties of tin must be examined in the state of block-tin ; what is commonly known by the name of tin, being nothing more than iron plates with a thin covering of this metal.

Tin has a silvery white colour, and by exposure to the air acquires a slight superficial tarnish, which does not appear to increase by time. Its specific gravity is about 7.9. It is extremely soft, scarcely, if at all, elastic ; and when a piece of it is bent backwards and forwards, it gives a peculiar crackling noise. It is very malleable, and may be beaten into thin leaves.

I. Tin melts on the application of a moderate heat, equal to 442° Fahrenheit, by a long continance of which it is converted into a grey powder. This powder, which appears to be the first oxide of tin, when mixed with pure glass, forms a white enamel.

The grey oxide, when brought to a full red-heat takes fire ; and, acquiring an increase of oxygen, passes to a pure white colour. This white oxide, when the heat is considerably raised, loses a part of its oxygen and runs into fusion. The *grey oxide,* according to Proust, is composed of 80 parts of tin and 20 of oxygen ; the *white oxide* of 72 tin and 28 oxygen. The white oxide may be obtained at once by projecting tin into a crucible intensely heated, when the oxide rises in the form of flowers somewhat resembling those of zinc.

II. Tin is not oxidized at common temperatures by exposure to air with the concurrence of moisture ; a property which is the foundation of its use in covering iron.

III. Tin amalgamates readily with mercury ; and this compound is much used in the silvering of looking-glasses. It is formed by adding gradually three parts of mercury to twelve of tin melted in an iron ladle, and stirring the mixture.

IV. Tin dissolves in sulphuric acid, which takes up, when concentrated and heated, half its weight. It is dissolved also by this acid, diluted with about a fourth its weight of water, and heated. During both these processes, sulphurous acid is disengaged ; and, in the latter, a pellicle of sulphur forms on the surface of the solution, which precipitates on cooling. When saturated, the solution deposites, after a while, needle-shaped crystals of sulphate of tin. If the sulphate be long boiled, a copious white precipitate subsides, which will not again dissolve. It is composed of the white oxide, retaining only a small portion of acid, and constituting in fact a *sub-sulphate.*

V. When nitric acid highly concentrated is poured upon tin filings, very little effect is produced; but when a small quantity of water is added, a violent effervescence follows; and the metal is reduced to a bulky powder, which is the white oxide retaining a little acid. If more water be added, an acid liquor is obtained, holding very little tin in solution. Tin, however, is slowly dissolved, without effervescence, in nitric acid greatly diluted. The solution is yellow and deposites oxide of tin by keeping.

VI. Muriatic acid, undiluted, is the proper solvent of tin. To one part of tin, in a tubulated retort, two parts of concentrated muriatic acid are to be added, and heat applied. The solution is complete, with the exception of a small quantity of black powder, which has not been sufficiently examined; and the acid takes up about one fourth of its weight of tin.* The solution has always an excess of acid; is perfectly limpid and colourless; and contains the metal at the minimum of oxidation. It has a tendency, however, to acquire a farther proportion of oxygen, and should, therefore, be carefully preserved from contact with the air. This property of absorbing oxygen is so remarkable, that it may even be applied to eudiometrical purposes. It has, also, the property of reducing, to a minimum of oxidizement, those compounds of iron in which the metal is fully oxidized. For example, it reduces the red sulphate to the green. It is a test also of gold and platina, as already noticed, and blackens the solution of corrosive sublimate. With hydro-sulphurets it gives a black precipitate.

VII. Tin may be brought to combine with the oxigenized muriatic acid, by first forming it into amalgam with mercury, triturating this with an equal weight of muriate of mercury, and distilling the mixture. Or the same compound may be formed, according to Proust, by distilling a mixture of eight ounces of powdered tin and twenty-four ounces of corrosive sublimate. The result is a liquid which emits dense white fumes, when exposed to the air, and was formerly termed the fuming liquor of Libavius. It gives no precipitate at all with muriate of gold or muriate of mercury—affords a yellow sediment with hydro-sulphuret of potash—dissolves a farther portion of the metal without effervescence, and is then changed into the common muriate.

This compound, according to the researches of Adet, is an oxigenized muriate of tin, perfectly free from water, and having a

* On the preparation of muriate of tin, see Berard, *Annales de Chimie*, lxviii. 78; or Nicholson's Journal, xxvi.

strong affinity for that fluid. Hence arises its fuming property; for the white vapours, which exhale when the bottle is unstopped, arise from the union of the salt with the moisture of the air.

VIII. The nitro-muriatic acid (formed by mixing two or three parts of muriatic acid and one of nitric) dissolves tin abundantly, with violent effervescence, and with so much heat, that it is necessary to add the metal slowly by successive portions. The solution is apt to congeal into a tremulous gelatinous mass; and if water be added, it is partly decomposed, and some oxide separated. The solution, used by the scarlet dyers, is prepared with that dilute nitric acid called single aqua-fortis, to each pound of which are added from one to two ounces of the muriate of soda or ammonia. This compound acid is capable of taking up about an eighth its weight of tin.

IX. Acetic acid (distilled vinegar) by digestion with tin filings takes up a portion of the metal, and acquires an opalescent or milky appearance. The solution is decomposed by the action of the air, and deposites an insoluble oxide.

Tin dissolves in tartaric acid; and the solution is applied to the useful purpose of *wet-tinning*, the process for which may be seen described in Aikin's Dictionary, ii. 427.

X. The oxide of tin, combined with sulphur, affords a compound of a bright gold colour and lustre, which has hence been termed *aurum musivum*.

XI. Tin forms useful alloys with many of the metals. *Pewter* is one of these; and the best kind of it is entirely free from lead, being composed chiefly of tin with small proportions of antimony, copper, and bismuth. A mixture of tin and lead, in about equal parts, composes the common *plumbers' solder*.

SECTION XI.

Lead.

LEAD has a blueish white colour; and, when recently cut or melted, considerable lustre, which soon, however, tarnishes. Its specific gravity is 11.352. Its malleability is sufficient to allow its being beat into very thin leaves; and it may be drawn into wire which has less tenacity, however, than that of most other metals.

The melting point of lead, according to Morveau, is 590° Fahrenheit; but according to Mr. Crichton of Glasgow it is 612°. Exposed to a red-heat, with free access of air, it smokes and sublimes, and gives a grey oxide, which collects on surrounding cold

bodies. It is slowly oxidized, also, by exposure to the atmosphere at common temperatures; and more rapidly, when exposed alternately to the action of air and water.

Lead appears to be susceptible of forming four distinct oxides. 1. The *yellow oxide* may be obtained by decomposing nitrate of lead with carbonate of soda, and igniting the precipitate. This oxide is tasteless, insoluble in water, but soluble in potash and in acids. When heated, it forms a yellow semi-transparent glass. It consists, according to Proust, of 91 metal and 9 oxygen, or according to Dr. Thomson of 89.7 lead and 10.3 oxygen.

Another form of the yellow oxide is that which is known in commerce by the name of *massicot ;* and the same oxide, it appears, is the basis of the carbonate of lead, employed as a pigment under the name of white lead.

2. Another oxide of lead, with rather a less proportion of oxyygen, has been formed by Proust, by boiling the nitrate of lead with metallic lead, and proceeding as before. The proportion of oxygen, however, differs so little from that of the former oxide, that it is doubtful whether we should consider the two as distinct compounds. It consists, according to Proust, of

91.5 lead

8.5 oxygen

_____

100

In this oxide, lead is at the minimum of oxidation.

3. By a farther exposure of massicot to heat, with a large surface, and the free access of air, it is converted into a beautiful red oxide known commonly by the name of *red-lead.* It is very heavy, its specific gravity being 8.940. By exposure to a red-heat, it yields oxygen gas, and loses from four to seven *per cent.* of its weight. It is not acted upon by acids. Its composition may be stated at 88 *per cent.* of lead and 12 of oxygen.

4. A still more highly oxidated compound of lead may be obtained by passing oxy-muriatic acid gas through water, in which the red oxide is kept mechanically suspended ; and by afterwards precipitating and drying the oxide. It is of a flea colour, and very fine and light in its texture. It is not soluble in nitric acid. When heated, it yields 9 *per cent.* of oxygen, and is converted into yellow oxide. It appears to be composed of about 80 lead and 20 oxygen.

The oxides of lead are easily vitrified, and have the property of

uniting with all the metals except gold and silver. Hence gold or silver may be purified by melting them with lead. The mixture is to be kept, for some time, in a state of fusion in a flat cup made of bone ashes, and called a *cupel* or *test*. The lead becomes vitrified, and sinks into the cupel, carrying along with it all the baser metals, and leaving the gold or silver on the surface of the cupel.

The oxides of lead give up their oxygen on the application of heat. When distilled in an earthen retort, they afford oxygen gas; and still more readily when distilled with concentrated sulphuric acid.

To procure oxygen gas, sulphuric acid may be poured on the red oxide of lead, contained in a gas bottle, and a gentle heat applied. The gas, thus obtained, after being agitated with water, is sufficiently pure for common purposes.

The oxides of lead are also reduced, by being ignited with combustible matter. Thus, when a mixture of red oxide of lead and charcoal is ignited in a crucible, a button of metallic lead will be found at the bottom of the vessel.

II. Pure water has no action on lead; but it takes up a small proportion of the oxide of that metal. When left in contact with water, with the access of atmospherical air, lead soon becomes oxidized and dissolved, especially if agitation be used. Hence the danger of leaden pipes and vessels for containing water, which is intended to be drank. Water appears also to act more readily on lead, when impregnated with the neutral salts that are occasionally present in spring-water.*

III. Sulphuric acid has no action on lead, except when concentrated and at a boiling temperature. It is then decomposed, and sulphurous acid is formed. The insolubility of lead in sulphuric acid occasions its being employed as the material for constructing the chambers, in which that acid is prepared, and even for boiling down the weak acid. Sulphate of lead, however, may be formed, either by adding sulphuric acid, or still better sulphate of soda, to any of the salts of lead. Its insolubility renders its formation of use as a step in mineral analyses, and hence it is necessary to know its exact composition. One hundred parts are stated by Berthier to consist of

* On the presence of lead in water, consult Dr. Lambe's " Researches respecting Spring Water." 8vo. London. Johnson.

69.34 lead
5.03 oxygen
25.63 acid

————

100

IV. Nitric acid, a little diluted, dissolves lead, with the extrication of nitrous gas. If the acid be in small quantity, a sub-nitrate is formed, which becomes soluble on adding more acid. A small portion remains undissolved, which Dr. Thomson finds to be oxide of antimony with a little silex. The solution is not decomposed when poured into water. By evaporation, it yields large regular crystals, which are soluble in about $7\frac{1}{2}$ parts of boiling water. From this solution, sulphuric and muriatic acids throw down an insoluble precipitate. The muriate of lead, after being washed with distilled water and dried, and then fused in a crucible, forms a substance, which has the semi-transparency and tenacity of horn, and is called *plumbum corneum*.

V. Carbonic acid may be brought to combine with lead, by precipitating the nitrate of lead with carbonate of soda, or by long exposure of thin sheets of lead to the vapour of vinegar. In the latter case we obtain the carbonate of lead or common white lead, which Bergman has shown to contain no acetic acid, though made by its intervention.

VI. When carbonate of lead is dissolved in distilled vinegar, and the solution crystallized, we obtain a salt of great utility in the arts, the super-acetate of lead, long known from its sweet taste under the name of *sugar of lead*.

It is in the form of small shining needle-shaped crystals, which are nearly equally soluble in hot and in cold water, *viz.* to about one fourth the weight of the fluid. The solution is decomposed by mere exposure to the air, the carbonic acid attracting the lead, and forming an insoluble carbonate. It is decomposed, also, by the carbonates and sulphates of alkali.

Super-acetate of lead consists of

26 acid
58 yellow oxide
16 water

————

100

By boiling in water a solution of 100 parts of super-acetate and 150 of litharge, this salt passes to the state of neutral acetate.

The taste of of this salt is less sweet ; it is less soluble in water ; and crystallizes in plates.   It is composed, according to Thenard, of

<div align="center">

17 acid
78 yellow oxide
5 water
———
100

</div>

All the solutions of lead are decomposed by sulphuretted hydrogen and by alkaline hydro-sulphurets. Hence these compounds are excellent tests of the presence of lead in wine or any other liquor, discovering it by a dark coloured precipitate. Hence, also, characters traced with solution of acetate of lead become legible when exposed to sulphuretted hydrogen gas. The same property explains, too, the effect of alkaline hydro-sulphurets in blackening the glass bottles, in which they are kept. The effect is owing to the action of the sulphuretted hydrogen on the oxide of lead which all white glass contains.

VII. The oxides of lead decompose muriate of soda.—Mix two parts of finely powdered red-lead with one of common salt, and form the whole into a paste with water, adding more, occasionally, as the mixture becomes dry. The alkali will be disengaged, and the muriatic acid will unite with the oxide of lead. Wash off the alkali, dry the white mass, and fuse it in a crucible. It will form the pigment called mineral, or patent yellow.

VIII. Lead unites in its metallic state with sulphur; and affords a compound of a blue colour with considerable brilliancy called *galena*. It is composed of 86 lead and 14 sulphur. Beside this there is another compound in which the sulphur forms 20 parts in 100; and which may be called the *super-sulphuret*.

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SECTION XII.

Zinc.

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ZINC is of a brilliant white colour with a shade of blue. Its specific gravity varies from 6.86 to 7.1, the lightest being the purest.   By particular treatment it becomes malleable,* and may be beat into leaves or drawn into wire.

I. Zinc is melted by a moderate heat, *viz.* at about 680° Fahrenheit, and the fused mass, on cooling, forms regular crystals.

* The discovery of the malleability of zinc is announced by Mr. Silvester in the Philosophical Magazine, vol. xxiii.

II. Though not much altered by exposure to the air at a low temperature, yet it is rapidly oxidized by one amounting to ignition.

When kept in a degree of heat, barely sufficient for its fusion, zinc becomes covered with a grey oxide. But when thrown into a crucible, or deep earthen pot, heated to whiteness, it suddenly inflames; burns with a beautiful white flame; and a white and light oxide sublimes, having a considerable resemblance to carded wool. This oxide, however, when once deposited, is no longer volatile; but, if exposed to a violent heat, runs into glass. It has been examined with much attention by Proust, who finds it to consist of 80 parts of zinc and 20 oxygen. When exposed to heat in a retort or covered crucible, it gives up part of its oxygen, and assumes a yellow colour, constituting an oxide which consists of 88 parts of zinc and 12 of oxygen. By oxidation to the maximum, Gay Lussac found that 100 parts of zinc take 24.41 oxygen, or about 19 *per cent*.

III. Zinc readily dissolves in diluted sulphuric acid, which evolves, during its action on this metal, hydrogen gas; and the gas, when obtained, holds in combination a portion of the metal. A stream of it, burned in Cuthbertson's apparatus (pl. iv. fig. 34,) has been found, if recently prepared, to occasion the fusion of the platina wire, though the pure gas is destitute of this property. This hydrogen gas, holding zinc in solution, may also be obtained by a process of Vauquelin. A mixture of the ore of zinc, called blende, or calamine, with charcoal, is to be put into a porcelain tube, which is to be placed horizontally in a furnace, and, when red-hot, the vapour of water is to be driven over it. The gas that is produced, however, is a mixture of carbonic acid, carburetted hydrogen, and hydro-zincic gas. The zinc is deposited on the surface of the water, by which this gas is confined; but, if burned when recently prepared, the gas exhibits, in consequence of this impregnation, a blue flame.

The solution of zinc in sulphuric acid shoots into regular crystals. This salt is soluble in $2\frac{1}{2}$ parts of water; and its solution is not precipitated by any other metal. Its composition is variously stated; but if, as Bergman says, 100 parts of the salt give 61.24 of ignited sulphate of barytes, it should consist of

39   water
20.4 acid
40.6 oxide of zinc

——

100

Mr. Smithson, however, states it, when perfectly deprived of water, to consist of equal parts of oxide of zinc and sulphuric acid.

IV. Nitric acid, moderately strong, acts on zinc with great violence. The solution, by evaporation, crystallizes, and affords a deliquescent salt.

V. Muriatic acid, a little diluted, acts on zinc and evolves hydrogen gas of great purity. The solution is clear, but cannot, by evaporation, be brought to crystallize. The dry salt, however, may be sublimed, and passes over in a half solid state, from which circumstance it has been called butter of zinc. When rapidly evaporated, it yields a thick extract, which has somewhat of the viscidity of bird-lime.

VI. Acetate of zinc may be formed either by directly dissolving the white oxide in vinegar, or by mingling the solutions of super-acetate of lead and sulphate of zinc. An insoluble sulphate of lead is formed, and the acetate of zinc remains in solution. By evaporation it affords a crystallized and permanent salt.

VII. Zinc is oxidized by being boiled with pure alkaline solutions, and a portion of the oxide remains dissolved. A similar compound may be obtained, by projecting a mixture of nitre and zinc filings into a red-hot crucible.

VIII. Zinc, in its metallic state, has very little affinity for sulphur. A mixture of the white oxide of zinc and flowers of sulphur combines, however, into a yellowish brown mass. Water, impregnated with sulphuretted hydrogen, decomposes, after some time, the solutions of zinc, and forms a yellow precipitate, which is probably a hydro-sulphuret.

IX. Zinc combines with phosphorus. The phosphuret of zinc is of a whitish colour and a metallic lustre not unlike lead. It has some malleability, exhales a phosphoric smell, and, at a high degree of heat, burns like common zinc.

X. Zinc is capable of furnishing alloys with most of the other metals. Of these the most useful, brass, has already been mentioned in the section on copper.

SECOND CLASS.

METALS THAT ARE BRITTLE AND EASILY FUSED.

SECTION XIII.

Bismuth.

BISMUTH has a redish white colour, and is composed of broad brilliant plates adhering to each other. Its specific gravity is 9.822, but is increased by hammering. It breaks, however, under the hammer, and hence cannot be considered as malleable; nor can it be drawn out into wire.

I. Bismuth is one of the most fusible metals, melting at 476° Fahrenheit; and it forms, more readily than most other metals, distinct crystals by slow cooling.

II. When kept melted at a moderate heat, it becomes covered with an oxide of a greenish grey or brown colour. In a more violent heat it is volatile, and may be sublimed in close vessels; but, with the access of air, it emits a blue flame, and its oxide exhales in the form of a yellowish smoke, condensible by cold bodies. This oxide is very fusible; and is convertible, by heat, into a yellow transparent glass. It is the only oxide of bismuth, with which we are distinctly acquainted; and consists, in 100 parts, of 89.3 bismuth and 10.7 oxygen.

III. Sulphuric acid acts on bismuth, and sulphurous acid is disengaged. A part of the bismuth is dissolved; and the remainder is changed into an insoluble oxide.

IV. Nitric acid dissolves bismuth with great rapidity. To one part and a half of nitric acid, add, at distant intervals, one of bismuth, broken into small pieces. The solution is crystallizable. It is decomposed when added to water; and a white substance is precipitated, called magistery of bismuth, or pearl-white. It consists of oxide of bismuth with a small proportion of nitric acid. This pigment is defective, inasmuch as it is liable to be changed by sulphuretted hydrogen, and by vapours of putrifying substances in general.

V. Muriatic acid acts on bismuth. The compound, when deprived of water by evaporation, is capable of being sublimed, and affords a soft salt, which deliquesces into what has been improperly called butter of bismuth.

VI. Bismuth is capable of forming the basis of a sympathetic ink. The acid, employed for this purpose, must be one that does

not act on paper, such as the acetic. Characters written with this solution become visible, when exposed to sulphuretted hydrogen.

VII. Bismuth is capable of being alloyed with most of the metals, and forms with some of them compounds of remarkable fusibility. One of these is Sir Isaac Newton's *fusible metal*. It consists of eight parts of bismuth, five of lead, and three of tin. When thrown into water, it melts before it is heated to the boiling point. It is from this property of forming fusible alloys, that bismuth enters into the composition of several of the *soft solders*, which, indeed, is its principal use.

Bismuth has the singular property of depriving gold of its ductility; even when combined with it in very minute proportion. This effect is produced by merely keeping gold in fusion near bismuth which is raised to the same temperature.

SECTION XIV.

Antimony.

I. ANTIMONY, as it occurs under that name in the shops, is a natural compound of the metal with sulphur in the proportion of 75 antimony and 25 sulphur. To obtain it in a metallic state, the native sulphuret is to be mixed with two thirds its weight of acidulous tartrite of potash (in the state of crude tartar,) and one third of nitrate of potash deprived of its water of crystallization. The mixture must be projected, by spoonfuls, into a red-hot crucible; and the detonated mass poured into an iron mould greased with a little fat. The antimony, on account of its specific gravity, will be found at the bottom adhering to the scoriæ, from which it may be separated by the hammer. Or three parts of the sulphuret may be fused in a covered crucible with one of iron filings. The sulphur quits the antimony, and combines with the iron.

II. Antimony, in its metallic state, (sometimes called *regulus of antimony*) is of a silvery white colour, very brittle, and of a plated or scaly texture.

III. It is fused by a moderate heat; and crystallizes, on cooling, in the form of pyramids. In close vessels it may be volatilized, and collected unchanged.

IV. It undergoes little change when exposed to the atmosphere at its ordinary temperature; but when fused, with the access of air, it emits white fumes, consisting of an oxide of the metal.

This oxide had formerly the name of *argentine flowers of antimo-ny*. The vapour of water, brought into contact with ignited anti-mony, is decomposed with so much rapidity, as to produce a vio-lent detonation.

V. Antimony combines with phosphorus and sulphur. With the latter an artificial sulphuret is formed, exactly resembling the native compound, which last may be employed, on account of its cheapness, for exhibiting the properties of this combination of an-timony.

1. When native sulphuret of antimony (frequently called crude antimony) is slowly roasted in a shallow vessel, it gradually loses its sulphur, the metal attracts oxygen, and is converted into a grey oxide. This, being melted in a strong heat, acquires a red-ish colour, and runs into a glassy substance, transparent at its edg-es, and termed *glass of antimony*. It consists of eight parts of oxide and one of sulphuret, with ten *per cent.* of silex. The same quantity of oxide and two of sulphuret give an opake compound, of a red colour inclining to yellow ; and called *crocus metallorum*. With eight parts of oxide and four of sulphur, we obtain an opake mass of a dark red colour, called *liver of antimony*. In all these compounds, the oxide is at its minimum of oxidation ; for the per-oxide is incapable of dissolving the sulphuret.

2. When fused with potash, a triple compound is formed, composed of alkali, sulphur, and antimony. Or the combination may be effected, in the humid way, by boiling the powdered na-tive sulphuret with pure potash. The solution, on cooling, depos-ites an hydro-sulphuretted oxide, in which the oxide prevails, call-ed *kermes mineral*. The addition of a dilute acid to the cold so-lution, precipitates a compound, having the same ingredients, but a larger proportion of sulphur, and called *golden sulphur of anti-mony*.

3. When the sulphuret of antimony is detonated with powder-ed nitre, the sulphur is oxigenated by the oxygen of the nitric a-cid ; sulphate of potash is formed, and an oxide of antimony is ob-tained, varying in its degree of oxigenizement, with the propor-tion of nitre which has been employed. The oxide remains, after washing away the sulphate with boiling water. If four times its weight of nitre be employed, the metal gains 32 *per cent.* of oxy-gen, and acquires somewhat of the character of an acid ; since it forms, with potash, a crystallizable compound.

VI. Antimony is dissolved by most of the acids. Sulphuric a-

cid is decomposed by it; sulphurous acid being disengaged, and an oxide formed, of which a small proportion only is dissolved by the remaining acid. Nitric acid dissolves this metal with great vehemence; muriatic acid acts on it by long digestion; but the most convenient solvent is the nitro-muriatic acid, which, with the aid of heat, dissolves it from the native sulphuret. With oxigenized muriatic acid, it forms a compound of a thick consistence, formerly called butter of antimony. This may be obtained, by exposing black sulphuret of antimony to the fumes of oxigenized muriatic acid, and by subsequent distillation; or by distilling the powdered regulus with twice its weight of corrosive muriate of mercury. The metal becomes highly oxidized, and unites with muriatic acid in its simple state. On pouring this compound into water, a white oxide falls down, called *powder of algaroth.*

VII. Antimony, it has been supposed by Thenard, is susceptible of several degrees of oxidation; but these, according to Proust, may be all reduced to two. The first oxide may be obtained by pouring the muriate of antimony into water, and washing the precipitate with water containing a small quantity of potash. When dry it is of a dirty white colour, without any lustre. It melts at a moderate red-heat, and becomes opake on cooling. It is composed of

$$81.5 \text{ antimony}$$
$$18.5 \text{ oxygen}$$
$$\underline{\hspace{3cm}}$$
$$100$$

The oxide at the maximum may be procured by collecting the flowers of antimony already described, or by causing the nitric acid to act on the metal, or by projecting it into melted and red-hot nitre. This oxide is of a white colour, and is much less soluble in water than the protoxide. It is, also, less fusible, and may be volatilized at a lower temperature, forming white prismatic crystals of a silvery lustre. It is composed of.

$$77 \text{ antimony}$$
$$23 \text{ oxygen}$$
$$\underline{\hspace{3cm}}$$
$$100$$

VIII. Antimony enters into combination with most of the metals. It destroys the ductility of gold, even when it composes only $\frac{1}{2000}$th of the whole mass, or when its fumes alone come into contact with melted gold. The most important of its alloys is

that which it forms with lead. In the proportion of one part to sixteen of lead, it composes the metal for printers' types.

SECTION XV.

Tellurium.

I. TELLURIUM was discovered, by Klaproth (Contributions ii. 1,) in an ore of gold. His process, for extracting it, consists in the solution of the ore by nitro-muriatic acid, dilution with water, and the addition of pure potash, which throws down all the metals that are present; and, when added in excess, re-dissolves a white precipitate, which it at first occasions. To the alkaline solution, muriatic acid is then added; a precipitate again appears; and this, when dried, and heated with one twelfth its weight of charcoal, or with a small quantity of oil, in a glass retort, yields tellurium, in the form of small brilliant metallic drops, lining the upper part of the body of the retort.—One hundred parts of the ore yield above 90 of tellurium.

II. 1. The colour of this metal is tin-white, verging to lead-grey; it has considerable lustre, and a foliated or scaly fracture. It is very brittle; is fusible at a temperature below ignition; and, excepting osmium and quick-silver, is the most volatile of all metals. It is the lightest of the metals, having the specific gravity of only 6.185.

2. It is oxidized when heated in contact with air; and burns with a sky-blue flame, edged with green. Upon charcoal, before the blow-pipe, it inflames with a violence resembling detonation; exhibits a vivid flame; and entirely flies off in a grey smoke, having a peculiarly nauseous smell. Its oxide is not reduced without the addition of combustible matter.

3. It is soluble in nitric and nitro-muriatic acids. The saturated solution is decomposed by the mere addition of water, which throws down a white powder; but this is again dissolved on adding more water. From its solutions it is precipitated in a metallic form, by iron, zinc, tin, and even by muriate of tin. Carbonated and pure alkalis precipitate the telluric oxide of a white colour; and the oxide is re-dissolved by an excess of alkali or carbonate. Alkaline sulphurets throw down a dark brown or blackish precipitate. Tincture of galls produces a flocculent yellow precipitate. The solutions of this metal in acids are not decomposed by prussiate of potash; a property which tellurium possess-

es in common with gold, platina, iridium, osmium, rhodium, and antimony.

SECTION XVI.

Arsenic.

I. Arsenic, as it is to be found in the shops, occurs in the state of a white oxide, from which the metal may be obtained by the following process. Mix two parts of the white oxide with one part of black flux (prepared by detonating, in a crucible, one part of nitre with two of crystals of tartar ;) and put the mixture into a crucible. Invert over this another crucible ; lute the two together, by a mixture of clay and sand ; and apply a red-heat to the lower one. The arsenic will be reduced ; and will be found lining the inside of the upper crucible in a state of metallic brilliancy, not unlike polished steel. Its specific gravity is 8.31. It is so extremely brittle, that it may be reduced to powder in a mortar.

II. Arsenic is oxidized by mere exposure to the atmosphere. It soon becomes tarnished ; loses its metallic lustre ; and is changed into a blackish oxide.

III. It is readily fusible, and is volatilized at 356°. In close vessels it may be collected unchanged ; but when thrown on a red-hot iron, it burns with a blue flame and a white smoke ; and a strong smell of garlic is perceived.

IV. All the mineral acids act on arsenic ; but not considerably, unless they are heated. In the oxigenized muriatic acid gas, however, arsenic burns vehemently.

V. A mixture of oxy-muriate of potash and arsenic furnishes a detonating compound, which takes fire with amazing rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with a knife point. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once, the arsenical mixture burns with the rapidity of lightning, while the other burns with comparatively extreme slowness.

VI. Arsenic combines with most of the metals. It has the property of giving a white stain to copper. Let a small bit of metallic arsenic, or a mixture of the white oxide with a little *black flux*, be put between two small plates of copper ; bind these closely to-

gether with iron wire; and heat them, barely to redness, in the fire. The inside of the copper plates will be stained white.

VII. The white oxide of arsenic has the following properties :

1. It has an acrid taste, and is highly poisonous.

2. It is soluble in water, which, at the ordinary temperature, takes up one eightieth. According to La Grange, it is soluble in one twenty-fourth of cold water, or one fifteenth of hot. The solution has an acrid taste, and reddens vegetable blue colours. When slowly evaporated, the oxide crystallizes in regular tetrahedrons. It is, also, soluble in 70 or 80 times its weight of alcohol, and in oils. At 383° Fahrenheit it sublimes ; or, if suddenly heated out of the contact of air, runs into glass. From the experiments of Proust, it appears to consist of

75.2 arsenic

24.8 oxygen

100

3. Oxide of arsenic combines with the pure alkalis to saturation ; and hence it fulfils one of the principal functions of an acid. It has therefore been called *arsenous acid*, and its compounds *arsenites*. They may be formed by simply boiling the arsenous acid with a pure alkaline solution.

4. The arsenous acid, or rather the arsenic which it contains, by distillation with sulphur, affords either a yellow substance, called orpiment, or a red one, termed realgar. The oxygen, uniting with sulphur, escapes in the form of sulphurous acid.

Both these compounds are sulphurets of arsenic, varying in the proportion of their components. The hydro-sulphurets, also, throw down a yellow precipitate from solutions of arsenous acid. Sulphate of copper, mixed with arsenite of potash, gives a beautiful precipitate, called, from its discoverer, Scheele's green.

5. By repeated distillation with nitric acid, arsenous acid is changed into *arsenic acid*. The same change is effected, also, by exposure to the vapour of oxigenized muriatic acid, and the expulsion, by heat, of the common muriatic acid. By both these processes, a white concrete substance is obtained, termed arsenic acid. The process recommended by Bucholz is to mix two parts by weight of muriatic acid of the specific gravity 1.200, twenty-four parts of nitric acid of the specific gravity 1.25, and eight parts of white oxide of arsenic. The whole may be evaporated to dryness, and gently ignited in a crucible.

VIII. 1. The arsenic acid has a sour, and at the same time, a metallic taste. It reddens vegetable blues; attracts humidity from the atmosphere; and effervesces strongly with solutions of alkaline carbonates. When evaporated it assumes the consistence of jelly and does not crystallize. It is a most active poison. According to Thenard it contains 36 *per cent.* of oxygen; but Proust makes the proportion only 34.6, and his determination is coincident with that of Bucholz. With alkalis, earths, and oxides, the arsenic acid constitutes a class of salts called arsenates. The arsenate of potash may be obtained in a more simple manner, by detonating, in a crucible, a mixture of nitrate of potash with arsenous acid.

2. When tin is dissolved in arsenic acid, an inflammable gas is disengaged, as was observed by Scheele, consisting of hydrogen gas, holding arsenic in solution. It may be obtained, also, by adding powdered metallic arsenic to a mixture of diluted sulphuric acid and zinc filings.

This gas (to which, perhaps, the name of *arsenuretted hydrogen* is best adapted) has the following properties.

(*a*) It is a permanently elastic and invisible fluid, of the specific gravity, compared with common air, of 0.5293.

(*b*) It has a fetid smell, resembling that of garlic.

(*c*) It extinguishes burning bodies.

(*d*) It is not absorbed by water in any notable degree; and has no effect on the blue colours of vegetables.

(*e*) It burns with a lambent white flame, and a disagreeable odour; and emits during combustion, fumes of arsenous acid.

(*f*) When mingled with oxigenized muriatic acid gas, heat is produced, a diminution ensues, and metallic arsenic is deposited. Soap bubbles, blown with a mixture of this and oxygen gases, burn with a blue flame, a white smoke, and a strong alliaceous smell.

(*g*) A stream of arsenuretted hydrogen gas, issuing from a bladder fitted with a stop-cock, and set on fire in a large receiver, filled with oxygen, burns with a blue flame of uncommon splendour.

(*h*) One cubic inch of the gas contains about one fourth of a grain of metallic arsenic.

For its remaining properties, consult Tromsdorff's memoir in Nicholson's Journal, vi. 200.

THIRD CLASS.

BRITTLE AND DIFFICULTLY FUSED.

SECTION XVII.

Cobalt.

I. COBALT may either be obtained from a substance, which may be purchased under the name of Zaffre, by fusing the zaffre with three times its weight of black flux; or it may be purchased, at a moderate price, in a metallic form.

To obtain cobalt in a perfectly pure state, Tromsdorff recommends, that the zaffre should be, three times successively, detonated with one fourth its weight of dry nitre, and one eighth of powdered charcoal. After the last of these operations, the mass is to be mixed with an equal weight of black flux, and the cobalt reduced. The metal is then pulverized, and detonated with thrice its weight of dried nitre. This oxidizes the iron to its maximum; and acidifies the arsenic; which last unites with the potash. Wash off the arsenate of potash, and digest the residue in nitric acid. This will take up the oxide of cobalt, and leave the oxide of iron. Evaporate to dryness; re-dissolve in nitric acid; filter the solution; and decompose it by a solution of potash. The oxide of cobalt, now obtained, may be reduced by the black flux, as before directed.

II. Cobalt has a greyish white colour, inclining somewhat to pink. Its specific gravity is 7.7; it is brittle and easily reduced to powder; is not fusible with a less heat than 130° of Wedgwood; and, when slowly cooled, may be obtained crystallized in irregular prisms.

By exposure to the atmosphere cobalt is tarnished, but not oxidized to any extent. In an intense heat it burns with a red flame; but, if pure, it is not easily oxidized by a moderate temperature. Its oxide is of a deep blue, approaching to black. This, from the experiments of Thenard, appears to be the first oxide. It may be obtained, also, by precipitating the nitrate of cobalt with potash. The precipitate is at first blue, but when dry becomes black. It dissolves readily in muriatic acid, giving a solution which is green when concentrated, and red when diluted. Its solutions in sulphuric and nitric acids are always red.

When this oxide is exposed to the atmosphere, it gradually absorbs an additional dose of oxygen; and becomes olive green.

Treated with muriatic acid, it gives oxy-muriatic acid gas, and a red solution is obtained.

When either of the two preceding oxides is heated in the open air, it passes to a flea-brown colour, which gradually becomes black. This is the metal oxidated to its maximum. The peroxide dissolves with effervescence in muriatic acid, and with a copious disengagement of oxy-muriatic acid gas. It is insoluble, however, in sulphuric and nitric acids, till it has parted with oxygen enough to reduce it to the minimum state. It is incapable, also, of being dissolved in pure alkalis, or of tinging vitrifiable mixtures blue.

According to the experiments of Proust, 100 parts of the *protoxide* consist of

$$83\tfrac{1}{2} \text{ metal}$$
$$16\tfrac{1}{2} \text{ oxygen}$$

$$\overline{100}$$

And 100 of the *peroxide* of

$$75 \text{ metal}$$
$$25 \text{ oxygen}$$

$$\overline{100*}$$

The black or peroxide, heated for half an hour at the bottom of a crucible, loses a part of its oxygen, and is reduced to the state of protoxide.

III. Cobalt is magnetic; at least this property is generally imputed to it even by late writers; but Mr. Chenevix suspects that it is owing to the presence of a small admixture of iron.

IV. The best solvents of cobalt are the nitric and nitro-muriatic acids; and the solutions have the singular property of forming sympathetic inks. One part of cobalt, or, still better, of zaffre, may be digested, in a sand-heat, for some hours, with four parts of nitric acid. To the solution, add one part of muriate of soda; and dilute with four parts of water. Characters written with this solution are illegible when cold; but when a gentle heat is applied, they assume a beautiful blue or green colour.† This experiment is rendered more amusing, by drawing the trunk and

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* Philosophical Magazine, xxx. 340.

† For some ingenious speculations on the cause of these phenomena, consult Mr. Hatchett's paper on the Carinthian molybdate of lead. (Philosophical Transactions, 1796.

branches of a tree in the ordinary manner, and tracing the leaves with a solution of cobalt. The tree appears leafless, till the paper is heated, when it suddenly becomes covered with beautiful foliage.

V. Oxide of cobalt is precipitated by carbonated alkalis from the nitric solution, at first of a peach-flower colour, and afterwards of a lilac hue. The crystals of nitrate of cobalt, thrown into a flask full of liquid potash, are immediately decomposed. A blue precipitate is formed, which, if the flask be immediately closed, passes to violet, and afterwards to red by becoming the *hydrate* or *hydro-oxide* of cobalt. This compound is soluble in cold carbonate of potash and tinges it red. The oxide is not soluble in this liquid. The hydrate loses from 20 to 21 *per cent.* of water by heat, and is reduced to protoxide.

VI. Oxalic acid throws down, from solutions of cobalt, a rose-coloured precipitate.

VII. Cobalt may be brought to combine with sulphur and phosphorus; but the compounds have no peculiarly interesting properties.

VIII. It may be alloyed with most of the metals, with the exception of bismuth and zinc.

Cobalt, when oxidized, is the basis of *zaffre*. This is generally prepared by roasting, from the ore, its volatile ingredients; and mixing with the remainder three parts of sand, or calcined flints. Zaffre, when fused, forms a blue glass; which, when ground and washed, is the substance termed smalts, used as a colouring substance for linen, and for imparting a blue colour to glass.

SECTION XVIII.

Manganese.

I. MANGANESE never occurs in a metallic state; the black substance, known by that name, being a compound of manganese, with a large proportion of oxygen. The metal is obtained, by mixing this oxide, finely powdered, with pitch, making it into a ball, and putting this into a crucible, with powdered charcoal, one tenth of an inch thick on the sides, and one fourth of an inch deep at the bottom. The empty space is then to be filled with powdered charcoal, a cover is to be luted on, and the crucible exposed, for one hour, to the strongest heat that can be raised.

II. This metal is of a dusky white colour, and bright and shining in its fracture. Its specific gravity is about 6.850. It is very

brittle, and even less fusible than iron, requiring a heat of 160°
Wedgwood to melt it.   It is attracted by the magnet; but only
in consequence of its being contaminated with a small quantity of
iron.   When exposed to the air it soon crumbles into a blackish
brown powder, in consequence of its oxidation, and becomes in suc-
cession grey, violet, brown, and finally black.

When heated with the access of air, it passes through succes-
sive shades of black, and finally acquires a green colour. (La
Grange, ii. 64.) It seems capable of forming three distinct oxides,
viz. the white, the red, and the black.

The *white oxide* may be precipitated from the nitric solution
(effected by the intervention of sugar) by adding potash.   It con-
sists of 80 parts of manganese and 20 of oxygen.   By exposure to
the air, it is changed into black oxide.

The *red oxide* may be precipitated from the sulphate of man-
ganese.   It consists of 74 manganese and 26 oxygen.

The *black oxide* is a production of nature, and is the substance,
which is employed in making the oxy-muriatic acid and for other
purposes of the arts.   It is composed, according to Fourcroy, of
60 parts of manganese and 40 oxygen.

III. The metal is soluble in acids, but most readily in the ni-
trous.   The muriatic solution is precipitated by the addition of
water only.   It is precipitated by alkalis in the form of a white ox-
ide.

IV. The black oxide of manganese gives up its oxygen when
distilled alone in a retort, or still more readily and abundantly, if
distilled with a mixture of sulphuric acid.

V. The black oxide of manganese is dissolved by the muriatic
acid; but, before solution, it yields part of its oxygen to one por-
tion of the muriatic acid, which escapes in an oxigenized state
(see chap. xiii.)   The solution has a brownish colour.   Alkalis
throw down from it a white precipitate, which, by exposure to the
air, becomes yellow, and finally black.

VI. The black oxide contains too much oxygen to dissolve in
nitric acid; but when, to a portion of this acid, in contact with the
oxide, a little sugar is added, and heat is applied, the oxide is dis-
solved.

VII. The black oxide of manganese imparts to borate of soda,
when melted with it, a violet colour.   When this is effected by
the blow-pipe, the colour may be destroyed by the interior flame,

and again re-produced by the exterior one, or by a small particle of nitre. (See Klaproth, vol. i. page 243, a.)

VIII. When powdered manganese and nitre are mixed together, and thrown into a red-hot crucible, the nitric acid is decomposed, and we obtain a compound of highly oxidized manganese with potash. This compound has the singular property of exhibiting different colours, according to the quantity of water that is added to it. A small quantity gives a green solution; a farther addition changes it to a blue; more still to a purple; and a still larger quantity to a beautiful deep purple.

The experiment may be varied, by putting equal quantities of this substance into two separate glass vessels, and pouring on the one hot, and on the other cold water.—The hot solution has a beautiful green colour, and the cold one is of a deep purple. The same material, with water of different temperatures, assumes various shades of colour, depending on the state of oxidizement of the metal. Hence this has been termed the chameleon mineral. This property is destroyed by a very small quantity of sulphuret of potash.

IX. The rose-colour of solutions of manganese, in sulphuric and phosphoric acids, disappears by exposure to the light of the sun, and is restored when removed into darkness. This effect depends on the de-oxidation of the metal by the sun's rays.

X. Manganese, in its metallic state, cannot be brought to combine with sulphur, though a native compound of these two substances has been examined by Proust. The oxide, however, unites with sulphur by fusion in the proportion of eight of the former to three of the latter; and a compound is obtained of a green colour, which gives out sulphuretted hydrogen gas by the action of acids.

XI. Manganese unites with most of the metals, and composes alloys; none of which are distinguished by important properties.

SECTION XIX.

Chrome.

This metal is found in an acidified state, and combined with oxide of lead, in the red-lead ore of Siberia; in the state of an oxide, in the green ore accompanying the red one; and in the emerald, to which it communicates its green colour.

I. To separate the chromic acid, the red-lead ore, reduced to powder, is boiled with twice its weight of carbonate of potash. An orange-yellow solution, composed of potash and chromic acid, is thus obtained; and when, to this, a mineral acid is added, and the liquor is evaporated, we obtain, 1. the salt formed by the acid, which has been united with the potash; 2. the acid of chrome, in long ruby-coloured prisms. From this acid the chrome may be obtained by heating it with charcoal, in the manner already often described. In the crucible a metallic mass is found, of a greyish white colour, formed of a number of needles crossing each other.

II. This metal is very brittle, infusible, and fixed.

III. It is susceptible of three states of oxidizement.—The first oxide is green, the second brown, and a farther dose of oxygen gives the chromic acid.

IV. The nitric acid alone exerts any remarkable action on this metal. Repeated distillation, with this acid, changes chrome into chromic acid, combinable with alkalis. The chromates of alkalis precipitate the salts of lead, of a beautiful yellow colour; which, if it could be procured in sufficient quantity, would be highly valuable in painting. Mercury is thrown down, of a cinnabarred hue; silver, of a carmine-red; and all its metallic combinations are distinguished by peculiar brilliancy of colour. The emerald derives its colour from the *oxide* of chrome; and the ruby from the *acid*. This property of imparting colour has suggested its name.

SECTION XX.

Molybdena.

I. The ore of molybdena was long mistaken for plumbago, or carburet of iron, to which it bears, externally, a strong resemblance. It is, in fact, a combination of sulphur and the oxide of molybdena. These two components may be separated by repeated distillation with nitric acid. To the ore of molybdena, in a retort, six times its weight of nitric acid are to be added, and the mixture distilled to dryness. This process must be repeated four or five times; and, at its close, both the sulphur and molybdena will be acidified. The sulphuric acid is expelled by heating the mass in a crucible; and any remaining portions are to be washed off with distilled water. The residue is a white heavy powder; which has an acid and metallic taste; is soluble in 560 parts of water; and forms salts with the alkalis and earths. The acid is

reduced by making it into a paste with oil, and exposing it, bedded in charcoal in a crucible, to an intense heat. Or (as Hielm recommends) the ore of molybdena may be repeatedly roasted in a moderate red-heat, till the whole is reduced to a fine powder, which may be passed through a sieve. The powder is to be dissolved in ammonia, the solution filtered, and evaporated to dryness. The residuum, being moderately heated with a little nitric acid, gives a white powder, which is the pure oxide of molybdena. This may be metallized by exposure to an intense heat with oil or powdered charcoal.

II. Molybdena has a whitish yellow colour, but its fracture is a whitish grey. It has not, hitherto, been obtained in any form, but that of small brittle grains. It is almost infusible by any artificial heat. Its specific gravity is 7.4.

III. It is readily oxidized when heated in contact with air, and is converted into a white oxide, which is volatilized in small brilliant needle-shaped crystals. This oxide has acid properties.

IV. According to Mr. Hatchett's experiments molybdena may be oxidized in four different degrees. 1. A black oxide is obtained from molybdenic acid, ignited with charcoal powder. 2. A blue one may be obtained by the same process not carried so far; or by immersing a plate of tin in a solution of the acid. 3. The third oxide has a green colour; and, having acid properties, is termed molybdenous acid. The fourth is the yellow molybdenic acid, obtained by the process already described.

V. The nitric, nitro-muriatic, and oxy-muriatic acids are the only ones that act on molybdena.

VI. The muriatic, and other acids, act on its oxides, and afford blue solutions.

VII. Molybdena unites readily with sulphur, and composes a substance, similar to the one from which the metal was originally obtained.

VIII. The molybdenic acid combines with alkalis, earths, and some of the imperfect metals. A small rod of zinc or tin is acted upon by a solution of the acid, which becomes blue, in consequence of the loss of a portion of its oxygen. The acid precipitates nitrates of silver, mercury, and lead; muriate of lead, and nitrate and muriate of barytes. Recent muriate of tin throws down, from the solution of molybdenate of potash, a beautiful blue precipitate.

SECTION XXI.

Uranium.

I. This metal was discovered by Klaproth, in a mineral which contains uranium combined with sulphur. The metal is separated from the sulphur, first by roasting; then dissolving the ore in nitro-muriatic acid, and precipitating by an alkali. An orange-coloured precipitate is obtained, which is an oxide of uranium. This may be reduced to a metallic form, in the same manner as the molybdenic acid.

II. Uranium is of a dark grey colour; and internally of a reddish brown. It has only been obtained in small grains of considerable hardness. Its fusion is very difficultly effected.

III. The metal is soluble only in nitric acid.

IV. Its oxide is of a yellow colour, and dissolves in acids. It is precipitated by alkalis; and is thrown down, of a redish brown colour, by prussiates. Sulphuret of ammonia gives a brownish yellow precipitate; and tincture of galls, a chocolate brown one.

V. The oxide of uranium is insoluble in alkalis, which distinguishes it from the oxide of tungsten. It is soluble, however, by alkaline carbonates.

SECTION XXII.

Tungsten.

I. Tungsten may be obtained from two different minerals. The one, consisting of the tungstic acid, united with lime, is called simply tungsten. In the other, termed Wolfram, it is united with iron and manganese. Its extraction from the former is the most simple process. One part of the tungstate of lime, and four of carbonate of potash, are fused together, and the mass is dissolved in 12 parts of boiling water. Nitric acid is then added, which unites with the potash, and precipitates tungstic acid. This acid, when reduced in the usual manner, yields tungsten; but the process of its reduction is a very difficult one, and frequently fails of success.

The tungstic acid may, also, be obtained from Wolfram, by fusion with three times its weight of nitrate of potash; or with twice its weight of carbonate of potash. The fused mass, dissolved in boiling water, and filtered, gives, on the addition of nitric acid, a precipitate of tungstic acid; or Wolfram, reduced to a fine powder, may be boiled with three times its weight of muriatic acid. As soon as the acid becomes hot, a yellow powder appears, and

the liquid becomes brown. When cold, decant the clear liquid, and wash the sediment repeatedly with water; then digest it, for some hours, with liquid ammonia, which will take up a part. Repeat these operations, till they cease to act on the substance. Evaporate the ammoniacal solution to dryness, and calcine the salt. The acid of tungsten remains, in the proportion of more than half the weight of Wolfram which has been employed.

II. Tungsten has the following characters:

1. It has a greyish white colour, like that of iron, and a good deal of brilliancy. It is not magnetic. Its specific gravity, according to D'Elhuyarts, is 17.6; or according to Messrs. Allen and Aikin 17.22. It is only, therefore, surpassed in density by gold and platina.

2. It is extremely hard and brittle. It requires, for fusion, a temperature of at least 170° Wedgwood.

3. It is oxidized by the action of heat and air. Its first oxide is black. The second is yellow, and is commonly termed tungstic acid.

4. The tungstic acid has no taste; is insoluble in water; but remains suspended in it, and in this state has no action on vegetable colours. Exposed to heat in a platina spoon, it assumes a deep green colour. Calcined with the contact of air, its yellow colour becomes deeper, and passes to a green, and, after some hours, grey. The deficiency of several acid properties has induced Vauquelin to withdraw it from the class of acids, and to arrange it among the oxides. It combines with alkalis; but so do the oxides of tin, zinc, antimony, and arsenic.

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FOURTH CLASS.

REFRACTORY METALS.

SECTION XXIII.

Titanium.

I. TITANIUM is obtained from a mineral found in Hungary, &c. called red schorl, or titanite; and, also, in a substance from Cornwall, termed menachanite. It was in the latter substance that it was originally discovered by Mr. Gregor of Cornwall; and its characters have since been more fully investigated by Klaproth, Vauquelin, and Hecht, Lovitz, and Lampadius. To separate it from the first compound, the mineral is to be reduced to powder, and fused with twice its weight of potash. When the fused mass,

after cooling, is dissolved in water, a white oxide of titanium remains.

Menachanite is to be first fused with potash in a similar manner; and to the alkaline solution, muriatic acid is to be added. This dissolves the oxide of iron, and precipitates the white oxide of titanium, still, however, contaminated by some iron.

II. The oxide of titanium is reduced, by exposure to an intense heat, moistened with oil, and surrounded by powdered charcoal. A blackish blistered substance is obtained, some points of which have a redish colour. Lampadius states its colour to be that of copper, but deeper; and its lustre to be considerable. It is brittle, but when in thin plates has considerable elasticity. When this is boiled with nitric acid, no remarkable effect ensues, but the bright spots disappear, and are succeeded by a white compound. Nitro-muriatic acid forms, also, a white powder, which remains suspended in it. Sulphuric acid exhibits a similar appearance; sulphurous acid is disengaged; and the titanium is partly changed to a white oxide, and partly dissolved. Muriatic acid dissolves titanium, but not its oxide.

III. The solution of titanium gives a white precipitate with carbonates of alkali; a grass green, mixed with brown, with prussiate of potash; and a dirty dark green, with hydro-sulphurets. Infusion of galls precipitates a redish brown substance, which, if the solution be concentrated, has the appearance of coagulated blood. A rod of tin, immersed in the solution, imparts to the liquid around it a fine red colour; and a rod of zinc a deep blue one.

IV. Titanium tarnishes by exposure to the atmosphere, and is oxidized when heated with access of air. It is susceptible of three stages of oxidizement. The first oxide is blue or purple, the second red, and the third white. The white oxide is the only one, with the composition of which we are accurately acquainted. It has been shown, by Vauquelin and Hecht, to consist of 89 parts of the red oxide and 11 parts of oxygen.

V. Titanium appears to be incapable of uniting with sulphur; but Mr. Chenevix has succeeded in combining it with phosphorus.

The only alloy of any consequence, which it forms, is with iron. It is of a grey colour, interspersed with brilliant particles, and is quite infusible.

SECTION XXIV.

Columbium and Tantalium.

COLUMBIUM was discovered by Mr. Hatchett, in a mineral belonging to the cabinet of the British Museum, supposed to be brought from Massachusetts, in North-America. By alternate fusion with potash, and digestion with muriatic acid, the mineral was decomposed ; the acid combining with oxide of iron, and the alkali with a peculiar metallic acid, separable by the addition of diluted nitric acid, which threw down a copious white sediment.

This acid has not yet been reduced ; but from its properties, there can be little doubt that it has a metallic base. It is insoluble in nitric acid ; but when fresh precipitated, it combines both with the sulphuric and muriatic. It unites also with alkalis : and both solutions are colourless. Prussiate of potash gives an olive-coloured precipitate ; tincture of galls, a deep orange ; and hydro-sulphuret of ammonia, one of a chocolate colour.

Tantalium.

This metal was discovered by Mr. Ekeberg, an eminent Swedish chemist, in two different fossils, called Tantalite and Yttro-tantalite, both of which are found in Finland. In the one it occurs combined with iron and manganese ; in the other, with the earth called yttria. (See *Annales de Chimie*, xliii. 281.) From these ores it is obtained, by treating them alternately with caustic fixed alkali, and muriatic or nitro-muriatic acid. The alkaline solution, being supersaturated with an acid, lets fall a white powder, which is oxide of tantalium. The following are the characteristic properties of tantalium, as enumerated by Mr. Ekeberg :

1. It is not soluble in any acid, in whatsoever state the mineral is taken, and whatever means are employed.

2. Fixed alkalis attack it, and dissolve a considerable quantity, which may afterwards be precipitated by acids.

3. The oxide of this metal is white, and does not acquire any colour, by exposure to a high temperature with access of air. Its specific gravity, after being made red hot, is 6.500.

4. It melts with phosphate of soda, and with borax, but does not impart to them any colour.

5. The oxide of tantalium, ignited with charcoal, melts and agglutinates. It then presents a metallic lustre, and a shining fracture of a greyish black colour. Acids change it again into a white oxide.

Though the oxides of tin and of tungsten are equally soluble with that of tantalium in fixed alkalis, yet the former is easily reduced, furnishing a ductile metal; and the oxide of tungsten dissolves in ammonia, is changed to a yellow colour by acids, and communicates colour to phosphate of soda and borax. The oxide of titanium differs from this, in being soluble by acids, and in tinging borax and phosphoric salts, when fused with them.

Considerable doubts have been entertained by several chemists, whether any essential difference exists between columbium and tantalium; and their identity appears now to be sufficiently established by some recent experiments of Dr. Wollaston. Having procured specimens of the tantalite and yttro-tantalite, from which tantalium may be separated, he compared its properties with those of oxide of columbium, furnished by Mr Hatchett, and obtained from a specimen in the British Museum.

The external characters of the mineral, which yields columbium, closely accord with those of tantalite. Both, also, yield a white oxide, combined with iron and managanese, and as nearly as possible in the same proportion. The white oxide, though not absolutely insoluble in sulphuric, nitric and muriatic acids, is (from whichever mineral it has been obtained) very nearly so. Its appropriate solvent is potash, which does not require to be absolutely free from carbonic acid. The whole of the oxide, thus dissolved, may be precipitated by an acid, and it is not re-dissolved by an excess of acid. The oxides from both minerals agree, also, in being soluble, when fresh precipitated, by oxalic, tartaric, and citric acids.

Infusion of galls, prussiate of potash, and hydro-sulphuret of potash, occasion no precipitation from the alkaline solution of either of these oxides; and, when a sufficient quantity of acid has been added to neutralize the redundant alkali, infusion of galls only throws down a precipitate which, in both cases, is of an orange colour. From these coincidences, there can be little room to doubt of the identity of columbium and tantal um; and as the discovery of Mr. Hatchett was some years previous to that of Ekeberg, it will be proper to retain the word columbium to express this peculiar metallic body.

SECTION XXV.

Cerium.

I. Cerium has been lately discovered, by Messrs. Berzelius and Hisenger of Stockholm, in a mineral from Bastnas, in Sweden,

which had been supposed to be an ore of tungsten. This discovery has been since confirmed by the unquestionable testimony of Vauquelin; who, after a careful examination of the mineral, concurs in opinion, that it contains the oxide of an unknown metal. From the planet Ceres, discovered about the same period, it has been called Cerium; and the mineral that contains it is termed Cerite. (See Nicholson's Journal, xii.)

II. To obtain the oxide of this new metal, the cerite is dissolved in nitro-muriatic acid, after being calcined and pulverized. The solution is filtered, neutralized with pure potash, and then precipitated by tartrite of potash. This precipitate, well washed, and afterwards calcined, is the oxide of cerium.

III. Cerium appears to be susceptible of two stages of oxidizement; the first oxide being white, and the second of a fallow red. The white oxide, by calcination, becomes red.

IV. Sulphuric acid, diluted with four times its weight of water, dissolves the red oxide. The solution, on being evaporated, yields crystals, some of which are orange, and others have a lemon-yellow colour. The sulphate is soluble only by an excess of acid. Its taste is saccharine mixed with acid.

V. Sulphuric acid readily unites with the white oxide; the solution is nearly colourless, but has a slight rosy tinge. It has a saccharine taste, unmixed with acidity, and yields white crystals.

VI. Nitric acid unites most easily with the white oxide. The solution is very sweet, and is not crystallizable. When decomposed by heat, it leaves a brick-coloured oxide.

VII. Muriatic acid dissolves the red oxide; and the solution crystallizes confusedly. The salt is deliquescent; soluble in an equal weight of water; and in three or four parts of alcohol. When this solution is concentrated, it burns with a yellow sparkling flame.

An infusion of galls produces, in muriate of cerium, a yellowish precipitate not very abundant. A few drops of ammonia throw down a very voluminous one of a brown colour, which becomes black and brilliant, by desiccation. By the action of heat, it assumes a brick-red colour.

VIII. Oxide of cerium unites readily with carbonic acid. This union is best effected, by precipitating a solution of the oxide with carbonate of potash. An effervescence ensues; and a white and light precipitate is formed, which assumes, on drying, a silvery appearance.

IX. Sulphuretted hydrogen does not unite with cerium.

X. The attempts of Vauquelin to reduce the oxide of cerium produced only a small metallic globule, not larger than a pin's head. This globule was not acted upon by any of the simple acids; but it was dissolved, though slowly, by nitro-muriatic acid. The solution was redish, and gave traces of iron; but it also gave evident marks of cerium, by the white precipitate which tartrite of potash and oxalate of ammonia threw down. The metallic globule, also, was harder, whiter, much more brittle, and more scaly in its fracture, than pure cast-iron.

XI. Hence cerium appears to be a volatile metal, unless it is volatilized in the state of an oxide, which remains to be ascertained by future experiments.

CHAPTER XIX.

VEGETABLE SUBSTANCES.

VEGETABLE substances, though they are all distinguished from each other by peculiar characters, present several circumstances of agreement in chemical properties. Oxygen, hydrogen, and carbon are their principal ingredients, to which a certain proportion of nitrogen is occasionally added; and variations in the proportions, and mode of combination, of these elements, constitute the great diversity, which subsists among the products of the vegetable kingdom. They are all susceptible of decomposition by heat alone; but we cannot, as in bodies of the mineral kingdom, proceed from a knowledge of their components to the actual formation of the substances themselves. It is not probable, indeed, that we shall ever attain the power of imitating nature in these operations. For in the functions of a living plant, a directing principle is concerned, peculiar to animated bodies, and superior to, and differing from, the cause which has been termed chemical affinity.

The productions, of which I am about to offer the chemical history, may be regarded as the *immediate* or *proximate* principles of vegetables; for we may presume, generally speaking, that they exist in the living plant in a state identical with that, under which chemical processes exhibit them. It is not so when we proceed to the *ultimate* analysis of vegetables; for, in that case, we obtain compounds, which formed no part of the vegetable structure, and which result from a new arrangement of the elements composing

it. Acetic and carbonic acids, for example, are obtained by the destructive distillation of several vegetable substances, in which neither of these acids existed ready formed, but only their elements.

The products of the vegetable economy are either situated in particular organs or vessels, or are distributed throughout the whole plant. Sometimes they reside in the root or stalk ; at others in the bark or leaves ; at others they are peculiar to the fruit, the flowers, the seeds, or even to particular parts of these organs. When thus insulated, they may readily be procured in a separate state ; and, in several instances, nothing more is required than the labour of collecting them. Thus gum exudes from some trees, and manna issues from the branches of others. Sometimes, however, we are presented with a variety of substances mingled together, and requiring separation by processes which are sufficiently simple, and which consist in repose, filtration, pressure, washing, distillation at a gentle heat, solution by water and alcohol, and similar operations, that do not alter the nature of the bodies submitted to them.

The number of principles, which have thus been extracted from vegetables, has of late years been greatly enlarged, and amounts at present to between thirty and forty. Of these, the greater part are certainly entitled, by a train of properties sufficiently characteristic, to rank as distinct compounds. But others seem to be so nearly allied to substances with which we have long been acquainted, that it can serve no useful purpose to assign them a different place in the system. The unnecessary multiplication, indeed, of vegetable principles, contributes rather to retard than to advance the progress of this difficult part of chemistry ; and it is only in cases of decided and unequivocal differences of qualities, that we should proceed to the establishment of new species.

SECTION I.

Vegetable Extract.

THE term Vegetable Exrtact is not to be understood in the sense which is generally annexed to it, as comprehending all those parts of vegetables which may be dissolved in water, and obtained in a solid form by evaporating the solution ; but is now limited to a distinct and peculiar substance. This substance may be obtained by evaporating, in a temperature below 212°, an infusion of saffron, prepared with boiling distilled water. It has the following properties :

1. It is cohesive, of a brownish colour, and generally of a bitter-ish taste, varying with the plant, from which it has been obtained.

2. It is soluble in cold water, but more copiously in hot; and the solution is always coloured. Hence the decoctions of certain substances (Peruvian bark for example) become turbid on cooling. The solution, exposed for a long time to the air, acquires a mouldy pellicle, and undergoes a sort of putrefaction.

3. When a solution of extract is slowly evaporated, it affords a semi-transparent mass; but rapid evaporation renders it perfectly opake. By repeated solutions in water, and evaporations, it acquires a deeper colour, and loses its property of being soluble in water, apparently in consequence of absorbing oxygen from the air.

4. Extract, exposed to the atmosphere, slowly imbibes moisture; or is imperfectly deliquescent.

5. It is soluble in alcohol and in liquid alkalis, but neither in ether nor in acids, which last even precipitate it from its solution in water.

6. Oxigenized muriatic acid, poured into a solution of extract, precipitates a dark yellow powder, which is no longer soluble in water, but dissolves in hot alcohol.

7. Extract has an affinity for alumine. When the sulphate or muriate of this earth is poured into one of extract, a precipitate appears, especially if the mixture be boiled. When linen or woolen thread, previously impregnated with a solution of alum, is boiled with a solution of extract, the thread is died a fawn colour, and the extract disappears in great part from the liquor.

8. Muriate of tin, and several other metallic salts, also precipitate extract, their oxides forming with it insoluble compounds.

9. Extract is not precipitated by a solution of tan.

These are the properties of extract, in the purest form under which we have yet procured it. As commonly obtained, however, it is combined with one or more, and frequently with a great number of other principles. In the sap of plants, it exists united with mucilage, gallic acid, tan, acetate of potash, and other neutral salts. Of the substance called *catechu*, it forms, according to the experiments of Mr. Davy, a considerable part; and being not easily dissolved by cold water, may be obtained by washing off the more soluble parts. The infusions, also, of most vegetable substances, hold extract in solution united with other principles.

From a recent series of experiments, Dr. Bostock is disposed to doubt whether there be any distinct principle, to which the ti-

tle of *extract* can with propriety be given. The re-agents, he finds, which have been pointed out as tests of extract, act also upon tan ; and the processes, for separating extract from the other parts of vegetable infusions, appear to him to be founded upon incorrect assumptions. He has not, however, examined the extract from saffron. (See Nicholson's Journal, xxiv. 204.)

SECTION II.

Mucilage, or Gum.

THIS substance, in a solid state, is generally known by the name of gum. Gum arabic may be taken as an example. It appears, however, from Dr. Bostock's experiments, that there is considerable variety in the chemical properties of different mucilages.

1. Gum is dry, brittle, and insipid, and undergoes no change by exposure to the atmosphere, except that the action of light destroys the yellow colour, which it frequently exhibits.

2. It is readily soluble in water, and forms a viscid solution, which may be kept a long time without undergoing any change ; but finally becomes sour.

3. It is insoluble in alcohol and in ether, the former of which separates it from water.

4. It is precipitated from water, in a thick curdy form, by acetate of lead ; and is thrown down by the red sulphate of iron, in the state of a brown semi-transparent jelly. Several other salts, also, have a similar effect, as may be seen in a table, in the fifth volume of Thomson's Chemistry, page 39, third edition. According to his experiments, the salts, containing mercury and iron at the maximum of oxidizement, are the most efficient in precipitating gum. The oxides of copper, antimony, and bismuth, are, also, acted upon by it ; for it prevents water from precipitating them in the state of sub-salts. The effects of re-agents on a solution of gum have been lately investigated, also, by Dr. Bostock (see Nicholson's Journal, xviii. 28 ;) and have been found to vary considerably in the different species of gum ; for example, in gum arabic, cherry-tree gum, and linseed mucilage.

5. Gum is soluble in pure alkalis, and in lime-water, and is precipitated unchanged by acids. Of the earths, silex seems to have the strongest affinity for it ; a solution of silicated alkali decomposing a very dilute solution of gum. (Thomson.) Dr. Duncan, jun. however, informs me, that this precipitate is produced only by solutions of the lighter coloured specimens of gum, which

have different properties from those of darker colour. The precipitation, when it does occur, Dr. Bostock suspects to take place, only in consequence of the lime which gum contains. Hence oxalic acid, also, produces a precipitate from the solution of gum arabic.

6. Diluted acids dissolve gum unchanged, and the concentrated ones decompose it. Strong sulphuric acid converts it into water, acetous acid, and charcoal; the last of which amounts to rather more than one fourth the weight of the gum, and exhibits slight traces of artificial tan. Nitric acid dissolves gum with a disengagement of nitrous gas; and the solution, on cooling, deposites a little saccholactic acid. Some malic acid is formed; and by continuing the heat, the gum is changed into oxalic acid, which bears the proportion of nearly one half of the weight of the gum. Oxy-muriatic acid, transmitted through a solution of gum, changes it into citric acid.

7. Gum and sugar readily combine; and by gentle evaporation of their mixed solutions, a transparent substance is obtained. From this, alcohol separates a part of the sugar, but the remainder continues in combination, and forms a substance, resembling that of which the nests of wasps are composed.

8. Gum, when submitted to destructive distillation in a retort, yields an acid, formerly called the pyro-mucous, but now ascertained to be merely the acetic, holding in solution a portion of essential oil, and some ammonia. Carburetted hydrogen and carbonic acid gases are also disengaged; and in the retort there remains charcoal, mixed with lime and phosphate of lime. Gum, therefore, is composed of oxygen, hydrogen, carbon, and (as may be deduced from its yielding ammonia) a little nitrogen. It appears to differ from sugar, not only in containing a less proportion of oxygen, but also by its combination with lime and nitrogen.*

Respecting the varieties of vegetable mucilage, which appear to be pretty numerous and well marked, much valuable information may be obtained from the paper of Dr. Bostock.

SECTION III.

Vegetable Jelly.

VEGETABLE jelly may be obtained from the recently expressed juices of certain fruits, such as the currant and gooseberry. When

* Cruickshank, Nicholson's Journal, 4to. ii. 409.

the expressed juice of these fruits is allowed to remain, for some time, in a state of rest, it partly coagulates into a tremulous soft substance, well known by the name of jelly. The coagulum, washed with a very small quantity of water, is jelly nearly in a state of purity.

Vegetable jelly, unless when tinged by the colour of the fruit, is nearly colourless; has a pleasant taste, and a tremulous consistency. It is soluble in cold water; but more copiously in hot, and the solution, if strong enough, again gelatinates on cooling. By long boiling it loses this last property, and is changed into a substance analogous to mucilage. When dried it is transparent. It combines readily with alkalis. Nitric acid converts it into oxalic acid, without disengaging any azotic gas. Its solution in water is precipitated by infusion of galls.

SECTION IV.
Sugar and Oxalic Acid.
ART. 1.—Sugar.

ALMOST all the sugar, which is applied to the common purposes of life, is derived from a plant, the growth of hot climates, called *Arundo Saccharrifera*. This plant produces strong canes, inclosing a soft pithy substance, which yield, by the compression of powerful machinery, a large proportion of sweet juice. The juice is evaporated in copper vessels, with the addition of a small quantity of slaked lime. During evaporation, a thick scum is formed, which is continually removed. The juice passes successively from larger to smaller boilers, till at length, in the last of these, it becomes thick and tenacious. When this happens, it is emptied into shallow wooden coolers, where the syrup forms a mass of small irregular crystals, enveloped in a treacly fluid. The whole mass is drained in hogsheads, in the bottoms of which holes are bored. The fluid, which separates, is called *melasses* or *treacle ;* and the dried crystals are exported to this country under the name of *raw* or *muscovado sugar*.

The subsequent process, which sugar undergoes, with the view of bringing it to the white and beautiful form of *loaf-sugar*, consists in its being re-dissolved in limewater, and in being boiled with a quantity of some coagulable substance, such as the whites of eggs or bullock's blood. These substances coagulate into a thick scum, which rises to the surface, carrying along with it the principal part of the impurities of the sugar. The solution, after

being evaporated to a due consistence, is let out into large conical earthen pots, with a hole at the apex of the cone, and each supported by an earthen jar. When the syrup has concreted into a solid mass, the plug is removed from the point of the cone, to allow the adhering liquid to drain off; and a mixture of pipe-clay and water is poured on the surface of the mould, and suffered to continue there four or five days. The moisture from this, slowly descending through the sugar, carries with it the remains of the darker coloured syrup; and the whole loaf, after being dried in a stove, is obtained of the proper degree of whiteness.

Besides the juice of the cane, sugar may be extracted, also, from several other vegetables. The juice which flows spontaneously from incisions made in the American maple-tree, affords a quantity sufficient to render it a process worth following. Ripe fruits contain sugar in considerable quantity, and by long keeping after they have been dried, it appears, in a granular state, on their surface. The juice of the carrot, and still more remarkably of the beet (*beta vulgaris*, Linn.) yield a considerable proportion of sugar. To obtain it from the latter vegetable, the roots, softened in water, are to be sliced, and the juice expressed. It is then to be boiled down with the addition of a little lime till about two thirds remain, and afterwards strained. These boilings and strainings are repeated alternately, till the liquid attains the consistence of syrup, when it is left to cool. The sugar thus extracted retains somewhat of the taste of the root; but it may be purified by the operation already described as used for the refining of West-India sugar, and it then loses its peculiar flavour. The quantity obtained varies considerably; but in general it may be stated at between four and five pounds from 100 pounds of the root, besides a proportion of uncrystallizable syrup. In Germany, the expense has been calculated at about three pence *per* pound; but this estimate is probably underrated.

From the experiments of Proust (Nicholson's Journal, xxi. 356,) it appears that a coarse sugar may be procured from grapes (of which many thousand tons are annually wasted in Spain,) at the expense of about eight pence *per* pound; or, under favourable circumstances, even for five pence.

Sugar is produced also in the process of malting, which consists in the conversion of fecula into sugar.

The following are its chemical properties:

1. Sugar is soluble in an equal weight of cold water, and almost to an unlimited amount in hot water. The latter solution

affords a liquid called syrup; from which, by long repose, transparent crystals of sugar separate, called *candied sugar.* Their form is that of prisms with four or six sides, bevelled at each extremity, or sometimes accuminated by three planes.

2. Alcohol dissolves, when heated, about one fourth its weight of sugar. The solution, by keeping, deposites large crystals of sugar.

3. Lime-water renders sugar more soluble. Alkalis unite with it, and destroy its taste. It may be recovered, however, unchanged, by adding sulphuric acid, and precipitating the alkaline sulphate by alcohol, which retains the sugar in solution. It unites, also, with the alkaline earths; and with barytes so strongly, that it appears to undergo a kind of decomposition.

4. Sugar has the property of rendering oils miscible with water.

5. The sulphurets, hydro-sulphurets, and phosphurets, appear to have the property of converting sugar into a substance not unlike gum. (Thomson's Chemistry, iv. 214.)

6. It is converted, by destructive distillation, into acetic acid, carburetted hydrogen, and carbonic acid gas, and charcoal. According to Lavoisier, it is composed of 64 oxygen, 28 carbon, and 8 hydrogen: but these numbers cannot be considered otherwise than as approximations to the truth.

Beside pure sugar, there are other saccharine substances, that bear a considerable resemblance to it. Manna is the inspissated juice which flows spontaneously from incisions in the bark of a species of ash (the fraxinus ornus.) It has been discovered, also, by Fourcroy and Vauquelin, to enter largely into the composition of the juice obtained by pressure from the onion. Besides sugar, it appears to contain a portion of mucilage and extract, to which its taste and other peculiar properties are owing.

The same may perhaps be said of honey. When treated with nitric acid it was found, however, by Mr. Cruickshank, to give very little less oxalic acid, than was obtained from an equal weight of pure sugar. Proust has considered honey itself as of two distinct species. Common yellow honey is of an uniform consistence and viscid; but, besides this, there is a granulated white kind, which has a tendency to become solid. From the latter he obtained by alcohol a white saccharine powder, which he considers as agreeing more nearly with the sugar of the grape than with common sugar.

Art. 2.—*Oxalic Acid.*

Sugar is acidified by distillation with nitric acid. To six ounces of strong nitric acid, in a stoppered retort, to which a large receiver is luted, add, by degrees, one ounce of lump-sugar, coarsely powdered. A gentle heat may be applied during the solution. Nitrous gas will be disengaged in great abundance. When the whole of the sugar is dissolved, distil off a part of the acid. The remaining liquor will form regular crystals (amounting to 58 parts from 100 of sugar,) which must be again dissolved in water' and crystallized. Lay this second crop of crystals on blotting-paper to dry.

Oxalic acid, may be procured, also, by a similar treatment of gum, and of various other vegetable, and even of some animal products.

The crystals of oxalic acid have the following characters :

1. They have a strong acid taste, and act powerfully on vegetable blue colours.

2. They dissolve in twice their weight of cold, and in an equal weight of hot water. They are soluble, also, in boiling alcohol, which takes up about half its weight ; and, though sparingly, in ether.

3. They effloresce in the air, and become covered with a white powder.

4. A red-heat entirely decomposes them, and leaves only charcoal. During distillation, a considerable quantity of inflammable gas is obtained ; and a portion of the acid is sublimed, unaltered, into the neck of the retort. From its analysis by destructive distillation, Fourcroy and Vauquelin have calculated that it consists of 77 oxygen, 13 carbon, and 10 hydrogen. The constitution of oxalic acid, however, has lately been investigated with much skill and attention by Dr. Thomson (Philosophical Transactions, 1807,) and with results, which differ considerably from these. The crystals, in their perfect state, he has proved to consist of

Real acid - 77
Water - - 23
———
100

And from an elaborate examination of the gases, obtained by destructive distillation, he concludes that 100 parts of real oxalic acid consist of

Oxygen　-　-　64
Carbon　-　-　32
Hydrogen　　-　4
_____

100

To the same chemist we are indebted, also, for an accurate analysis and history of the alkaline and earthy oxalates, of which the following is an abstract.

OXALATE OF POTASH forms flat rhomboidal crystals, terminated by dihedral summits. Its taste is cooling and bitter. At 60° Fahrenheit, it requires three times its weight of water for solution. There is, also, a salt formed of the same base and acid, but with a considerable excess of the latter. It is known, in commerce, by the name of *salt of sorrel*, but is more properly called SUPER-OXALATE OF POTASH. It forms beautiful four-sided prisms. The acid, which it contains, is double that in the oxalate ; or if we suppose 100 parts of potash, and denote the quantity necessary to convert it into oxalate by x, then $2\,x$ will convert it into super-oxalate.

QUADROXALATE OF POTASH was formed by Dr. Wollaston, by digesting the super-oxalate in nitric or muriatic acid. The alkali is divided into two parts, one of which unites with the mineral acid ; and the other half remains in combination with the oxalic acid. Hence the quadroxalate contains four times the acid that exists in the neutral oxalate, and twice as much acid as the super-oxalate ; or its acid may be denoted by $4\,x$.

OXALATE OF SODA readily crystallizes, and has a taste nearly resembling that of oxalate of potash. When heated, it falls to powder, and loses the whole of its water of crystallization. Soda is said to form, also, with oxalic acid a *super-oxalate*.

OXALATE OF AMMONIA is the most important of all the oxalates. It crystallizes in long transparent prisms, rhomboidal, and terminated by dihedral summits. Its taste is bitter and unpleasant. At the temperature of 60°, 1000 grains of water dissolve only 45 grains of the salt. The solution is of great use as a re-agent ; for it precipitates lime from all its soluble combinations, and discovers it even when in very minute quantities. Hence it is a most important instrument of analysis.

OXALATE OF LIME is an extremely insoluble salt. It may be formed, either by dropping oxalic acid into lime-water, or by mingling the solutions of a salt with base of lime and of any of the soluble oxalates. When very slowly dried at the temperature of

about 60° Fahrenheit, it is tolerably uniform as to its composition ; and consists according to Dr. Thomson, of

Acid	- -	59.2
Lime	- -	35.5
Water -	-	5.3

100

When rapidly dried, it is apt to concrete into hard lumps, which contain not less than 10 *per cent.* of water. It is soluble in nitric and muriatic acid ; and hence, in the use of oxalate of ammonia or oxalic acid as a precipitant, it is necessary to neutralize any excess of acid.

OXALATES OF BARYTES AND STRONTITES are white tasteless powders of very sparing solubility ; but these earths are said, with an excess of acid, to form soluble super-oxalates.

OXALATE OF MAGNESIA is a soft white powder, bearing a considerable resemblance to oxalate of lime. It is tasteless, and not sensibly soluble in water. Yet when oxalate of ammonia is mixed with sulphate of magnesia, no precipitate falls.

According to Dr. Thomson, 100 parts of oxalic acid saturate the following quantities of the several bases :

Ammonia	- -	34.12
Magnesia	- -	35.71
Soda	- - -	57.14
Lime	- - -	60
Potash	- - -	122.86
Strontian	- -	151.51
Barytes -	- -	142.86

And the composition of the different oxalates is shown by the following table.

One hundred parts of					Consist of	
					Acid.	Base.
Oxalate of ammonia	-	-	-	-	74.45	25.55
————— magnesia	-	-	-	-	73.68	26.32
————— soda	-	-	-	-	63.63	36.37
————— lime	-	-	-	-	62.50	37.50
————— potash	-	-	-	-	44.87	55.13
————— strontian	-	-	-	-	39.77	60.23
————— barytes	-	-	-	-	41.16	58.84

The above table is to be understood as applicable to the salts in their state of ordinary dryness. With the exception indeed of oxalate of potash, and perhaps of soda, Dr. Thomson is of opinion

that, when slowly and carefully dried, the proportion of water is so small, that it may be overlooked.

SECTION V.

Native Vegetable Acids and Acidula. *

NATIVE vegetable acids are such as are found, ready formed, in plants or their fruits, and require only pressure, and other simple processes, for their extraction. The following are the principal ones hitherto discovered.

1. Citric.	6. Benzoic.
2. Gallic.	7. Acetic.
3. Malic.	8. Prussic.
4. Tartaric.	9. Phosphoric.
5. Oxalic.	

ART. 1.—*Citric Acid.*

Citric acid exists in the expressed juice of the lime and lemon, along with a quantity of extractive matter and mucilage. The process, for obtaining it in a separate state, we owe to the ingenuity of Scheele. To the juice of the lime or lemon, contained in a vessel of earthen ware, or white wood, add, very gradually, finely powdered carbonate of lime (chalk or whiting,) and stir the mixture well after each addition. An effervescence will ensue; and as long as this arises, on adding fresh portions of chalk, more will be required. The exact proportion it is impossible to assign, on account of the variable strength of the acid juice. In general, from six to eight ounces of chalk are sufficient to saturate a wine-gallon of lime-juice. When it ceases to excite effervescence, and the liquor has lost its sour taste, leave the mixture to settle; decant the liquid, and add a quantity of water. Let the powder subside; the liquor be again decanted, and thrown away; and these operations repeated, till the water comes off nearly colourless. The insoluble precipitate consists of citric acid united with lime; add to it a quantity of sulphuric acid, of the density 1.8 equal to about three fourths the weight of the chalk which has been employed, and previously diluted with 20 parts of water; or the sulphuric acid may be poured, undiluted, upon the precipitate, suspended by stirring it in a considerable quantity of water.—Let the acid and precipitate remain together 24 hours; during which time

* By *acidula* are to be understood salts with an excess of acid, such as super-oxalate of potash, &c.

they must be frequently stirred. Then let the white sediment, which consists of sulphate of lime, subside ; decant the clear liquor; add more water till it comes off tasteless ; and mix all the liquors together. The solution, containing citric and sulphuric acids, and some mucilage, is to be evaporated in shallow earthen dishes, placed in a sand-heat. Reduce the liquid about three fourths its bulk by evaporation ; separate the sulphate of lime, which will be deposited, and again waste the liquor by a heat not above 212°, to the consistence of syrup.—Dark brown crystals will form on cooling, which must be set to drain ; and the remaining liquor, when again evaporated repeatedly, will continue to yield fresh crystals. To purify these, let them be dissolved in water ; and the solution again evaporated. After the second crystallization, their colour will be improved ; but it will require three or four crystallizations to obtain them perfectly white and well formed. In this state they are the pure citric acid.

The proportions, which I have recommended for the preparation of citric acid, differ a little from those, which have been deduced by Proust from his experiments. Four ounces of chalk saturated, he found, 94 ounces of lemon juice ; the citrate of lime weighed seven ounces four drachms. But the four ounces of chalk, or 32 drachms, contained only $17\frac{1}{4}$ drachms of lime ; and, from the analysis of citrate of lime, it appears to contain 70 parts of citric acid in 100. Hence the seven ounces four drachms contained $41\frac{1}{4}$ drachms of citric acid. But to expel the carbonic acid completely from four ounces of chalk, five ounces of sulphuric acid of commerce were found necessary. This proportion, therefore, he employed in decomposing the citrate of lime. Six ounces of the citrate, by two crystallizations, gave $3\frac{1}{2}$ ounces, or 28 drachms, of pretty large crystals ; from whence it follows that the whole $7\frac{1}{2}$ ounces would have given 4 ounces 3 drachms of citric acid. (Philosophical Magazine, x.)

The citric acid, which is made for sale, is generally prepared from lime-juice. The quantity of solid citric acid, in a gallon of this juice, varies from 14 to 18 ounces. The only method of ascertaining its proportion consists in adding, to a quantity of the juice, solution of pure potash till saturation is produced ; having previously determined, by direct experiments, how much of the alkaline solution is required to neutralize an ounce of crystallized citric acid.

Pure citric acid forms beautiful transparent crystals, consisting of two four-sided pyramids joined base to base, or sometimes of

rhomboidal prisms. An ounce of distilled water, at 60° Fahrenheit, dissolves an ounce and a quarter of these crystals, or at the boiling temperature twice its weight. The crystals do not attract moisture from the atmosphere. They are decomposed by a high temperature, and yield aëriform products of a kind which show them to be composed of carbon, hydrogen, and oxygen, in unknown proportions.

When treated with about three times its weight of nitric acid, the citric acid is converted partly into the oxalic, of which it gives half its weight. As the proportion of nitric acid is increased, that of the citric is diminished, till at length it disappears altogether, and acetic acid appears to be formed.

Citric acid readily unites with alkalis, earths, and metallic oxides.

CITRATE OF POTASH.—According to Vauquelin, 36 parts of crystallized citric acid, dissolved in water, require for saturation 61 of crystallized carbonate of potash; and the result is an extremely soluble and even deliquescent salt, composed of $55\frac{1}{2}$ acid and $44\frac{1}{2}$ alkali.

CITRATE OF SODA is a very soluble salt. Thirty-six parts of citric acid neutralize 42 of dry sub-carbonate of soda; and hence 100 parts of the citrate consist of 60.7 acid and 39.3 base.

CITRATE OF AMMONIA.—The same quantity of citric acid saturates 44 parts of sub-carbonate of ammonia; and affords a soluble and difficultly crystallizable salt, composed, in 100 parts, of 62 acid and 38 base.

CITRATE OF BARYTES consists of equal weights of acid and base. It is an insoluble salt of little importance.

CITRATE OF MAGNESIA.—Thirty-six parts of crystallized acid neutralize 40 parts of sub-carbonate of magnesia. Hence 100 parts of the salt contain 33.34 base and 66.66 acid. The salt is soluble, but not crystallizable.

CITRATE OF LIME.—Crystallized citric acid, dissolved in water, requires an equal weight of chalk for saturation. The compound, when neutral, is insoluble; but with an excess of acid it becomes readily soluble. It is probably composed of about 65 acid and 35 earth.

The METALLIC CITRATES have been but little examined. The compounds of this acid with the oxides of iron are of the most importance; from the use which is made of it as a discharger in calico-printing.

Art. 2.—*Gallic Acid.*

This acid exists in the gall-nut, along with tan and other substances. In Mr. Davy's experiments, 400 grains of a saturated infusion of galls, gave 53 of solid matter, composed of nine tenths tan and one tenth gallic acid. The acid may be obtained by exposing an infusion of galls in water to the air. A mouldy pellicle will form on the surface of the infusion ; and, after some months' exposure, small yellow crystals will appear on the inside of the vessel. These crystals must be dissolved in alcohol, to separate them from other substances, and the solution evaporated to dryness.

It may also be procured by sublimation. Pounded galls are to be put into a retort, and heat applied. The gallic acid will rise, and be condensed in the neck of the retort in a solid form. This process is recommended by Deyeux as preferable to any other. (See note 37 at the end of this vol.)

The gallic acid may be separated from the infusion of galls, by adding muriate of tin till the precipitate ceases to appear. This precipitate may be reserved for the experiments detailed under the article *Tan.* From the remaining solution the superabundant oxide of tin must be precipitated by sulphuretted hydrogen gas, and the clear liquor, on evaporation, yields crystals of gallic acid.

From one ounce of galls, according to Haussman, about three drachms of gallic acid may be obtained.

In Nicholson's 8vo. journal, vol. i. page 236, a very simple process for obtaining gallic acid is proposed by Mr. Fiedler. Boil an ounce of powdered galls, in sixteen ounces of water down to eight, and strain the decoction. Precipitate also two ounces of alum, dissolved in water, with a sufficient quantity of carbonate of potash, and, after having washed the precipitate extremely well, add it to the decoction, and digest the mixture for 24 hours, shaking frequently. The alumine combines with, and carries down, both the tan and extract ; and the filtered solution yields, by gentle evaporation, crystals of gallic acid.

By none of these processes, however, can gallic acid be obtained perfectly pure ; for it still, according to Mr. Davy, is contaminated with a small portion of extract.—To purify it, Deyeux advises its sublimation. Over a glass capsule, containing the impure acid, and placed in a sand-heat, another capsule is to be inverted, and kept cool.—On the impression of the heat, the acid rises into the upper one, in the form of white needle-shaped crystals.

The pure acid has the following characters :

1. Its crystals have the form of transparent plates or octohedrons. They have an acid and somewhat astringent taste.

2. Gallic acid burns with flame, when placed on a red-hot iron, and emits an aromatic smell.

3. It is soluble in 24 parts of cold, or three of boiling water. Alcohol, when cold, dissolves one fourth, or an equal weight when heated.[*]

4. The solution reddens blue vegetable colours, and effervesces with alkaline carbonates.

5. Nitric acid converts the gallic into oxalic acid.

6. It unites with alkaline solutions without producing any deposite ; but from watery solutions of lime, barytes, and strontites, it occasions a blueish precipitate. Of the combinations of earths with acids, it decomposes those only with base of glucine, yttria, and zircon.

7. It precipitates most metals from their solutions ; gold, silver, and copper, of a brown colour ; lead, white ; mercury, orange ; bismuth, yellow ; and iron, deep black. The precipitate from solutions of iron is soluble in an excess of acid. It forms the basis of ink, which, according to Deyeux, consists of carburetted oxide of iron, and gallate of iron.

8. By a moderate heat, it is sublimed without alteration, but a strong heat decomposes it ; and aëriform products are formed, which show it to consist of hydrogen, oxygen, and carbon in proportions not yet exactly determined.

A full and valuable history of the gallic acid, and the process for obtaining it, by Bouillon La Grange, may be consulted in Nicholson's Journal, xvii. 58.[*] This chemist has lately, however, expressed a doubt of the claim of the gallic acid to be considered as a distinct acid, and suspects that it is only a modification of the acetic. Its properties, he remarks, differ according to the method in which it has been prepared. (*Annales de Chimie*, lx. 156.)

Art. 3.—*Malic Acid.*

This acid exists in the juice of apples, gooseberries, and of some other fruits, and is found mixed with the citric, and occasionally with other acids. It may be obtained by evaporating the juice nearly to dryness, and then adding alcohol, which dissolves the

* The reader will find, also, much important matter on this subject in Messrs. Aikins' Dictionary of Chemistry, article Gall Nut, and in Dr. Bostock's papers in Nicholson's Journal, vol. xxiv.

acids, and leaves the mucilage. To this solution of citric and malic acids in alcohol, chalk is to be added to saturation, and the precipitate to be washed with boiling water, which takes up the malate of lime, and leaves the citrate. The solution of the malate of lime may then be decomposed by sulphuric acid.

Or the juice of apples may be saturated with carbonate of potash, and mixed with a solution of acetate of lead, till the precipitate ceases. This precipitate is to be washed with water, and dilute sulphuric acid is to be added, till the liquor acquires an acid taste, unmixed with any sweetness. The liquor is to be filtered, to separate the sulphate of lead, and evaporated. It yields no crystals, but a thick liquor of a cherry-red colour.

Vauquelin has shown that the malic acid may be obtained advantageously from the juice of house-leek *(sempervivum tectorum)* by adding acetite of lead, and decomposing the insoluble malate with sulphuric acid. It is formed, also, by the action of nitric acid on sugar. Equal weights of the two are to be distilled together, till the mixture assumes a brown colour. The oxalic acid may be separated by adding lime-water; after which, the remaining liquor is to be saturated with lime and filtered. On the addition of alcohol, a coagulum of malate of lime is formed, which may be dissolved in water, and decomposed, as before directed, by acetate of lead; and afterwards by sulphuric acid.

The malic acid is liquid, and incapable of being crystallized; for, when evaporated, it becomes thick and viscid, like syrup. It is very soluble in water. By keeping, it undergoes a kind of decomposition. Nitric acid converts it into oxalic acid. It unites with alkalis and earths. With lime it forms a salt which is almost insoluble in cold water, but readily soluble by hot; and in consequence of this last property, it may be easily separated from the oxalic, citric, and tartaric acids. It precipitates mercury, lead, and silver from nitric acid; and decomposes, also, the solution of gold.

Art. 4.—*Tartaric Acid, and its Combinations.*

The tartaric acid is generally obtained from the supertartrate of potash (common cream of tartar) by the following process:

Let 100 parts of finely powdered cream of tartar be intimately mixed with about 30 parts of pulverized chalk. This is best done by grinding them together in a mortar, and passing the mixture through a sieve. Let the mixture be thrown, by spoonsful, into eight or ten times its weight of boiling water; waiting for the

cessation of the violent effervescence, which is produced by each addition, before any more is thrown in. This method I find preferable to the entire solution of the cream of tartar in the first instance, which requires a very large quantity of water. If it should appear, from the effect of the liquor on litmus paper, that the chalk has not been added in sufficient quantity, more may be gradually used, till the colour of the litmus is no longer reddened.

By this operation, a quantity of insoluble tartrate of lime will be formed, which is to be allowed to subside, and washed, three or four times, with cold water. To the tartrate of lime, diffused through a sufficient quantity of water, concentrated sulphuric acid may be added, equal in weight to the chalk which has been employed. The mixture may be allowed to stand for 24 hours, during which it should be frequently agitated. Assay a little of the clear liquor, by pouring into it some solution of acetate of lead. A copious precipitate will be formed, which may either consist of tartrate of lead, or of a mixture of tartrate with sulphate of lead. To determine this, add diluted nitric acid, which dissolves the tartrate but not the sulphate. A small proportion of the latter is desirable, because the tartrate of lime cannot be wholly decomposed without an excess of sulphuric acid; but a large excess of that acid is injurious, from its re-acting on the tartaric acid, when heat is applied in the subsequent part of the process. The deficiency of sulphuric acid should be supplied by adding more; or a great redundance of it removed by the addition of a little chalk. The evaporation of the solution may now be carried on, in a manner precisely similar to that directed for the citric acid; and the crystals purified by a second solution and evaporation.

The liquor, remaining after the addition of chalk, consists of the neutral tartrate of potash. It may be decomposed by adding muriate of lime, till no farther precipitation ensues. An insoluble tartrate of lime falls down, which may be decomposed by sulphuric acid, in the way already directed. Or the tartrate of potash may be evaporated to dryness, and reserved for other purposes. If the tartrate of lime be formed by the first operation only, the product of crystallized acid amounts to between one fourth and one fifth the weight of the cream of tartar. But the double decomposition by muriate of lime considerably increases the quantity of acid produced.

Quicklime has been recommended as a substitute for chalk in this process; but I have never found that it could be employed with any advantage; for a quantity of caustic potash is set at lib-

erty by its action, which dissolves the tartrate of lime, and prevents it from precipitating. When chalk is employed for saturation, that part of the acid only is neutralized, which constitutes the *super*-salt; but with quicklime the operation is carried still farther, and the neutral tartrate, also, abandons its acid.

The tartaric acid forms regular crystals, the shape of which varies considerably according to the circumstances of their preparation, and especially to the greater or less excess of sulphuric acid, which has been employed. They require for solution five or six parts of water at 60° Fahrenheit; but are much more soluble in boiling water. The solution, like that of most other vegetable acids, acquires a mouldy pellicle by keeping.

Bergman exposed tartaric acid to distillation with nitric acid, in the manner of obtaining oxalic acid, but without being able to produce the latter acid. Hermbstadt, however, by using a very concentrated nitric acid, succeeded in converting the tartaric into the oxalic acid, and from six drachms of the former obtained four drachms and two scruples of the latter. Westrumb, also, was successful in the same attempt, and adds that the tartaric acid may be changed into the acetic by digestion with water and alcohol.

When distilled alone in a strong heat, the tartaric acid is decomposed; it yields a quantity of dark coloured acid liquor, which has erroneously been supposed to be acetic acid; and a large quantity of combustible gas is obtained. From the results of its destructive distillation, Fourcroy and Vauquelin have inferred that tartaric acid consists of

70.5 oxygen
19 carbon
10.5 hydrogen

From the recent experiments of Fourcroy and Vauquelin, it appears that the pyro-tartaric acid is a peculiar species. From the acetic it differs in being less volatile and less odorous: in being crystallizable by evaporation; and in affording, with potash, a salt which precipitates acetate of lead. It is distinguished from the tartaric acid, in not occasioning any precipitate from the acetates of lime, of barytes, or of lead; and in not forming, with potash, an insoluble salt when the acid is in excess.—Influenced by the results of these experiments, the same chemists submitted the pyro-mucous and pyro-lignous acids to a fresh and rigid examination, which terminated in the conviction that they both consist of acetic acid, holding in combination a quantity of empyreumatic

oil. (*Annales de Chimie*, lxiv. 42 ; or Nicholson's Journal, xxvi. 44.)

Tartaric acid unites with alkaline and earthy bases, and affords a distinct class of salts called tartrates.

TARTRATE OF POTASH may be obtained by adding sub-carbonate of potash either to cream of tartar, or to the solution of the crystallized acid, till all effervescence ceases. According to Von Packen 120 grains of sub-carbonate require for saturation 112 of pure tartaric acid. The resulting salt is very soluble, and even deliquescent. It is composed, according to Thenard, of

48 acid
43 base
9 water
———
100

SUPER-TARTRATE OF POTASH.—If into a solution of the neutral tartrate, we pour a solution of tartaric acid, a white powder falls down in great abundance, which is a compound of the neutral salt, and an additional quantity of acid. This is an example of the diminution of solubility, by an increased proportion of the acid ingredient of a salt. The tartaric acid, in this proportion, has even so strong an affinity for potash, that it separates this alkali from the mineral acids. Thus by adding tartaric acid to the muriate of potash, we obtain a precipitate of super-tartrate of potash.

The substance, which is known in commerce under the name of *tartar*, is an impure variety of this salt. When purified, it affords white crystals, which, by being reduced into powder, form the *cream of tartar* of the shops.

Super-tartrate of potash requires for its solution a very large quantity of water, not less than 120 parts of water at 60° Fahrenheit, or 30 at 212°. Hence its solution deposites the salt on cooling in such quantity as amounts almost to precipitation.

From the experiments of Thenard, its composition may be stated at

57 acid
33 potash
10 water
———
100

But of the 57 parts of acid, 37 are more than sufficient to neutralize the alkali ; and hence it may be stated, in different terms, to

be composed of 70 parts of neutral tartrate, 20 of acid, and 10 of water.

By the destructive distillation of super-tartrate of potash, Fourcroy and Vauquelin obtained, exclusive of acid and charcoal,[*] of

Pure dry sub-carbonate of potash	350
Tartrate of lime	6
Silex	1.2
Alumine	0.25
Iron and manganese	0.75

TARTRATE OF POTASH AND SODA may be formed by neutralizing cream of tartar with sub-carbonate of soda. The resulting salt is well known, from its being employed in medicine under the name of *Rochelle salt*. It requires, for solution, about five parts of cold water, but much less at the boiling temperature. From the experiments of Vauquelin it appears to be composed of 54 parts of tartrate of potash, and 46 parts of tartrate of soda.

The EARTHY TARTRATES have no particularly interesting properties. With the exception of those of magnesia and alumine, they are insoluble.

ART. 5.—*Benzoic Acid.*

This may be obtained from a substance termed gum benzöin or benjamin. The process consists in pulverizing a pound and a half of gum benzöin with four ounces of quicklime, and then boiling them for half an hour in a gallon of water, constantly stirring. When cold, the clear liquor is poured off; and what remains is boiled, a second time, in four pints of water, the liquor being poured off as before. The mixed liquids, after being boiled to one half, are filtered through paper; and muriatic acid is gradually added, until it ceases to produce a precipitate. Finally, after having decanted the liquid, the powder is dried in a gentle heat, and sublimed from a proper vessel, placed in a sand-bath, into cones of writing paper.

Benzoic acid has a peculiar and not a disagreeable odour. Its crystals are soft, and cannot be reduced to powder. It is volatilized, in white fumes, by a moderate heat. It requires for solution about 24 times its weight of boiling water, which as it cools, lets fall $\frac{19}{20}$ths of what it had dissolved. It is soluble in alcohol.

The composition of this acid has not been discovered; and the compounds, which it forms with alkaline and earthy bases, called

* Annales de Chimie, lxiv. 48.

BENZOATES, are too little known to admit of their being accurately described.

ART. 6.—*The Oxalic Acid*

Is also found native in the juice of sorrel, forming a salt with excess of acid, or an acidulum, and as appears from the experiments of Vauquelin, in the Rheum Palmatum.

ART. 7.—*Moroxylic Acid.*

Mr. Klaproth has lately discovered a new acid, combined with lime and extract, in a saline mass, which exudes from the trunk of the white mulberry, *morus alba*, L. It was collected, by Dr. Thomson, from trees in the botanic garden at Palermo ; and seems peculiar to those individuals that grow in hot climates. Its characters have not been fully ascertained. From its origin, it has been called, by Klaproth, MOROXYLIC ACID, and its compounds MOROXYLATES. (See Nicholson's Journal, 8vo. vii. 129.)

ART. 8.—*The Laccic Acid*

(Which, in strictness, should be classed among animal acids) is obtained from the white lac of Madras, from which, when liquefied, it oozes out in drops. It is in the form of a redish liquor, having a slightly bitter saltish taste ; but, on evaporation, it shoots into acicular crystals. It may be raised in distillation. It combines with carbonate of lime and soda, and excites effervescence. It precipitates barytic salts ; assumes a green colour with lime-water, and a purplish one with sulphate of iron. A full account of its properties, and of those of the substance that affords it, may be found in Dr. Pearson's paper in the Philosophical Transactions 1794.

ART. 9.—*Phosphoric Acid*

Exists in almost all vegetable substances, and particularly in all the varieties of grain, not however in a free state, but in combination chiefly with potash and lime. Hence the coal of almost all kinds of seeds affords phosphorus by distillation, a fact originally observed by Margraaf, and confirmed by the recent experiments of Saussure. (Nicholson's Journal, xxv. 279.)

ART. 10.—*The Prussic Acid*

Has been discovered in water distilled from bitter almonds, from the leaves of the laurel, and from peach blossoms. When the

distilled liquid is neutralized with potash, a crystallizable salt is obtained, the solution of which throws down prussian blue from the salts of iron. Vauquelin, also, obtained prussic acid by distilling water with a very gentle heat, from the kernels of apricots. (*Annales de Chimie*, xlv. 206.)

SECTION VI.

Fixed Oils.

1. THESE oils are obtained, by pressure, from certain vegetables; as the olive, the almond, linseed, poppy-seed, rape-seed, &c.

2. As thus obtained, they are generally found combined with mucilage, to the spontaneous decomposition of which is chiefly owing the change that oils undergo by keeping, called *rancidity*.

3. They are usually coloured, but may be deprived of colour by digestion with charcoal.

4. Their specific gravity is commonly between that of alcohol and water. Hence they sink in the former, and float on the surface of the latter fluid. They cannot, by strong agitation, be brought to combine with either of these fluids; but always separate on standing.* When the seeds, however, which contain them, are rubbed with water, especially if a little sugar be added, an imperfect solution is obtained called *an emulsion.* On adding an acid to this, the oil is detached, and floats on the surface.

5. Some of the fixed oils congeal, or become solid, by a very moderate reduction of their temperature; and others, as palm oil, are permanently thick, or form a soft solid like butter, at the temperature of the atmosphere.

6. They unite with alkalis, and form soap. The soap, however, which is commonly manufactured in this country, is made by combining the fixed alkalis with tallow. Of the processes followed in the preparation of soap, both from vegetable, and animal oils, an excellent description is given in Messrs. Aikins' Chemical Dictionary.

Soap is readily soluble in water. The solution is decomposed by acids, and by neutral salts with earthy bases. Hence hard waters, which contain earthy salts, curdle soap; their acid uniting with the alkali of the soap, and setting the oil at liberty. When a strong solution of soap is mixed with one of a metallic salt, a

* Olive oil is said to be soluble, in small proportion, in alcohol. (Nicholson's Journal, xvi. 166.

substance is formed, termed a metallic soap. The alkali unites with the acid of the salt, and the oil with the metallic oxide.

7. Fixed oils dissolve sulphur, and form a kind of balsam. They act also on phosphorus.

8. Their properties are changed by boiling with metallic oxides, those of lead for example. The mucilage unites with the oxide, which probably gives up a portion of its oxygen to the oil, and the oil is rendered drying, and fit for the use of the painter. If the oxide be added in larger proportion, the mass, when cold, composes a plaster.

9. Fixed oils, when distilled with a gentle heat, yield olefiant and carburetted hydrogen gases. A portion of the oil passes over, also, without decomposition. Hence they cannot be considered as absolutely fixed, but have received this name chiefly from a comparison with the essential or volatile oils. By repeated distillations the whole of any fixed oil may finally be changed into gaseous matter.

10. Fixed oils are extremely combustible ; and when burned in an apparatus, adapted for collecting the products of their combustion, they afford carbonic acid and water. It may be inferred, therefore, that they are composed of carbon and hydrogen, the proportions of which, according to the experiments of Lavoisier, are 79 of the former and 21 of the latter. From this statement, however, oxygen is excluded, which it is probable all fixed oils contain. Its presence indeed is almost demonstrated by Mr. Davy's experiments. When a globule of potassium, he observes, is introduced into any of the fixed oils made hot, the first product is pure hydrogen, which arises from the decomposition of the water absorbed by the crust of potash during exposure to the atmosphere. If the globule be previously freed from this crust, carburetted hydrogen is disengaged, coaly matter deposited, and a soap is formed. To generate the alkali, however, which this soap contains, oxygen must necessarily have been supplied by the decomposition of the oil. Mr. Davy has also found, in the products of their destructive distillation by heat, a proportion of water, to the production of which oxygen is essential. (Philosophical Transactions, 1808.)

11. Nitric acid acts with great energy on the fixed oils. In a small proportion, its chief effect is to render them thicker. When distilled together with a larger proportion of acid, the oil is decomposed, and nitrous gas disengaged ; oxalic acid remaining in the retort. Red and smoking nitric acid, when suddenly mixed

with a fixed oil, especially with the addition of a little sulphuric acid, occasions a violent combustion. Oxy-muriatic acid gas passed through them, thickens them and renders them tenacious like wax.

12. The fixed oils have a singular property, which has led sometimes to serious accidents. When mixed with lamp black, or with any light kind of charcoal, and even with several vegetable substances, as cotton, wool, or flax, the mixture, after some time, heats spontaneously, and at length bursts into flame. This combustion has sometimes been observed to take place in the waste cotton, employed to wipe the oil from machinery ; and has probably occasioned many of the dreadful fires, which have happened in cotton-mills, and for which no adequate cause could be assigned.

SECTION VII.

Volatile or Essential Oils.

WITH the exception of the oil from the rinds of the lemon and the orange, which are obtained by expression, the essential oils are procured, by distilling the vegetables that afford them, with a proper proportion of water. The oil either sinks to the bottom, or swims on the surface, of the water, according to its specific gravity.

1. These oils have a penetrating smell, and an acrid taste.

2. They are volatilized by a gentle heat. Hence the spot which they leave on paper may be removed by holding it at a small distance from the fire; but the stains from expressed oils are permanent.

3. They can, with difficulty, be brought to unite with alkalis.

4. They are soluble in alcohol.

5. They do not unite with water. With the intervention of a little sugar, however, they are combinable, in small proportion, with water.

6. When nitric acid is poured upon these oils, especially if it has been previously mixed with one fifth, or one sixth of sulphuric acid, the mixture bursts out into a violent flame. This experiment requires caution, as the inflamed oil is apt to be scattered about.

7. Several of them detonate, when rubbed with hyper-oxigenized muriate of potash, and take fire when poured into oxigenized muriatic acid gas.

8. Essential oils are thickened by long exposure to air. This

is owing, as Dr. Priestly first proved, to their absorbing oxygen, a fact which accounts, in some degree, for the injurious effects of fresh painted rooms.

9. Potassium decomposes the volatile oils when heated. Alkali is formed; a small quantity of gas is evolved; and charcoal is deposited.

CAMPHOR resembles the essential oils in many properties, but is not inflamed by nitric acid, which converts it into an acid, distinguished by peculiar properties, and termed the *camphoric acid*.

For this purpose, camphor is repeatedly distilled with four times its weight of nitric acid, till about 20 parts of acid have been employed. At each operation, the portion of camphor, which sublimes and escapes decomposition, is to be returned into the retort. The acid is susceptible of crystallization; the crystals effloresce in the air, and are sparingly soluble in water; they are combustible; and burn with a dense, aromatic smoke; they melt and sublime with a gentle heat, and dissolve in the mineral acids. They dissolve also in alcohol, and are not precipitated by water. With alkalis and earths they compose a class of salts called Camphorates.

A singular substance very much resembling camphor in its sensible and chemical properties, may be obtained by passing muriatic acid gas through essential oil of turpentine, which absorbs about a third of its weight. The oil of turpentine becomes thick, from an abundance of a white crystalline substance which forms in it. This may be separated by draining off the liquid; and is found rather to exceed the weight of the essential oil submitted to experiment.* It is white, crystalline, granular, volatile in a moderate heat, and has very much the smell of camphor. By exposure to the air, it soon loses its property of reddening vegetable blue colours. As to the theory of its production, Thenard is of opinion that no decomposition of the oil of turpentine takes place; but that the muriatic acid unites to it entire. Ordinary camphor of commerce, he supposes, from analogy, to be a compound of an essential oil and a vegetable acid.

SECTION VIII.

Resins.

RESINS are inspissated juices of certain plants, and are generally obtained by wounding their bark. Copal, or lac, may be taken

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* Thenard, *Memoires d' Arcueil,* ii.

as an example. Dragon's blood, guaiacum, sandarach, labdanum, common resin, and turpentine, are also varieties of this substance.

1. They have generally a yellow colour, and are imperfectly transparent. In specific gravity they exceed water.

2. They are dry, brittle, and extremely inflammable.

3. They dissolve in alcohol, ether, and essential oils; but not at all in water, which even precipitates them from the foregoing solvents.

4. Both acids and alkalis act on them; the pure alkalis most remarkably. The alkaline solution is clear, and may be diluted with water without decomposition; but acids immediately precipitate the resin. By mixing it with a solution of a metallic salt, the oxide is precipitated in combination with resin.

5. By long continued and repeated digestion with nitric acid, the resins afford a deep yellow solution, which has the property of precipitating animal gelatine, and agrees, therefore, with tannin. No oxalic acid is obtained by this process, a circumstance which distinguishes the resins from all other vegetable substances.

6. Concentrated sulphuric acid dissolves the powdered resins. If the solution be digested in a moderate heat, sulphurous acid is first evolved; in a few days this ceases; and a black porous coal remains, equal in weight to between a fifth and a third that of the resin which has been employed; whereas, by incineration in close vessels, scarcely $\frac{1}{100}$th part their weight of coal is obtained.

Acetic acid dissolves resins, which are precipitated from it by the addition of water.

7. Resins are the basis of varnishes, and are much used in medicine.

Balsams are liquid resins, holding in combination a proportion of benzoic acid.

Gum-resins, along with resin, have an admixture of extractive matter. They dissolve partly in water, and partly in alcohol. They are almost solely used in medicine. Asafœtida, gum-ammoniac, aloes, gamboge, myrrh, opium, &c. are varieties of gum-resin.

Guaiacum was observed by Mr. Hatchett to differ from other resins in giving oxalic acid by the action of nitric acid, and very little tannin. In other respects, also, it has been since shown, by Mr. Brande, to possess properties that do not agree with those of resins in general. (Philosophical Transactions, 1806.)

Amber is a resin possessed of peculiar properties. By distillation it yields a distinct acid, called the *succinic*.—To prepare this

acid, let a glass retort be half filled with powdered amber, and the remainder with fine dry sand. Lute a receiver, and apply a gentle heat. A portion of water first comes over, which is succeeded by a weak acetic acid. The succinic acid then sublimes; but is contaminated by a mixture of oil. It may be purified by solution and crystallization; and it then forms transparent white shining crystals, having the form of triangular prisms. They are soluble in 24 times their weight of water, and in boiling alcohol. The solution reddens the blue colour of turnsole, but not that of violets, and has an acid taste. It combines with alkalis, &c. and forms succinates, the most important of which is the succinate of ammonia. This salt decomposes all the solutions of iron; and affords an insoluble precipitate, composed of succinate of iron. Hence it is highly useful in the analysis of mineral waters.

SECTION IX.

Farina, or Fecula.

FARINA or fecula may be obtained from the flour of most varieties of grain, from the roots of the potatoe, and from almost every part of vegetables, by a very simple process. The grain in the state of fine powder, or the root well rasped, is to be washed with a quantity of *cold* water which becomes turbid, and, if the fecula is white, milky. The fecula, however, is not dissolved but merely suspended mechanically; and, after separating the fibrous and grosser parts by a sieve, it subsides to the bottom of the vessel.

The liquid, which contains the soluble parts of the vegetable, is to be decanted, and the farina washed by repeated affusions of cold water. It may afterwards be dried in a gentle heat.

From the analysis of Dr. Pearson,* we learn that 100 parts of the fresh potato root, deprived of skin, afford

Water 68 to 72
Meal 32 to 28

100   100

The meal is composed of three distinct substances; *viz.*

Fecula - - - -	15 to 17
Fibrous matter - - -	8 to 9
Extract or mucilage - -	5 to 6

28   32

* Repertory of Arts, iii. 383.

Some useful information respecting the quantity of fecula in different varieties of the potato, and the methods of separating it, has been given by Mr. Skrimshire in the 21st volume of Nicholson's Journal.

Common starch may be taken as an example of fecula. It will be found to have the following qualities :

1. It is not soluble in water, unless when heated to 160°; and if the temperature be raised to 180°, the solution coagulates into a thick tenacious transparent jelly. By evaporation at a low heat, this jelly shrinks, and at length forms a transparent brittle substance closely resembling gum. The solution of starch in a large quantity of water is precipitated by Goulard's extract of lead; but not by any other metallic salt.

2. Farina is insoluble in alcohol, and in ether.

3. Pure liquid alkalis act on starch; and convert it into a transparent jelly. The compound is soluble in alcohol.

4. Sulphuric acid dissolves it slowly; sulphurous acid is evolved; and so much charcoal is disengaged, that the vessel may be inverted, without spilling its contents.

5. Nitric acid, at the temperature of the atmosphere, acts on starch, and dissolves it; but no oxalic acid appears subsequently, unless heat be applied. Hot nitric acid is decomposed by starch, and oxalic acid is generated.

6. Starch, as it exists in grain, is spontaneously convertible into sugar. On this property is founded the process of malting.

7. Starch is said by Dr. Thomson to be capable of entering into chemical union with tan. (Nicholson's Journal, 8vo. ix. 74.) Of the existence of such a combination, however, Dr. Bostock has found reason to doubt. (Ditto, xviii. 33.)

8. When strongly heated, starch becomes first yellow, and afterwards a redish brown; it softens, swells, and exhales a penetrating smell. If the process be stopped, a substance is the result, which is employed by calico-printers under the name of *British gum.* Distilled in close vessels, it yields an acid, termed the pyromucous. This has been lately shown to be an impure form of vinegar.

9. It becomes sour when exposed in a moist state to the air.

SECTION X.

Gluten.

GLUTEN may be obtained from wheat-flour, by a very simple process. The flour is first to be formed, by the gradual addition

of a small quantity of water, into a soft and ductile paste. This is to be washed by a very slender stream of water, and, at the same time, to be constantly worked between the fingers. The water carries off the fecula, and for some time is rendered milky. When it passes off transparent, the washing may be discontinued; and the pure gluten remains in the hands.

The following are the properties of gluten :

1. It is of a grey colour, and has so much elasticity, that, when drawn out, it recovers itself like elastic gum. It has scarcely any taste, and does not melt or lose its tenacity in the mouth.

2. When exposed to a gentle heat, it dries very slowly, and becomes hard, brittle, semi-transparent, of a dark brown colour, and somewhat like glue. When broken it has the fracture of glass. In this state it is insoluble in water.

3. When kept moist, it ferments and undergoes a sort of putrefaction, emitting a very offensive odour. At the same time a portion of acid is developed, which is perceivable by its smell, and which considerably retards the putrefaction of the gluten. In this circumstance, chiefly, it differs from animal gluten.

4. When suddenly heated, it first shrinks; then melts, blackens, and emits a smell like that of burning horn. By distillation in close vessels, it yields a portion of water impregnated with carbonate of ammonia; a considerable quantity of brown fœtid thick oil; solid sub-carbonate of ammonia; and carburetted hydrogen gas. These products resemble, very closely, those of animal substances.

5. It is generally described to be insoluble in water, in alcohol, and in ether. After fermentation, it is partially soluble in alcohol, and the solution may be applied to the purposes of varnish. From the recent experiments of Dr. Bostock, gluten appears, however, by long digestion, to be partly soluble in water. The solution is precipitated by acetate and super-acetate of lead, by muriate of tin, and by other re-agents. (Nicholson's Journal, xviii. 34.)

6. All acids dissolve it, and alkalis precipitate it, but considerably changed, and deprived of its elasticity. It undergoes a similar change when dissolved in pure alkalis, and precipitated by acids.

7. It exists most abundantly in wheat-flour, of which it constitutes about one fourth, and is essential to its soundness; but it is found, also, in various vegetable juices. (See Proust on the Green Fecula of Vegetables, Nicholson's Journal, 8vo. iv. 273.)

SECTION XI.

Caoutchouc, or Elastic Gum.

CAOUTCHOUC is chiefly the product of two trees, which are the growth of Brazil ; the *Hoevea Caoutchouc* and *Jatropha Elastica.* When the bark of these trees is wounded, a white milky juice flows out, which speedily concretes in the air into an elastic substance ; and, when the juice is applied, in successive coats, upon clay moulds, it forms the globular bottles, which are brought to this country. By an immediate and careful seclusion from air, the juice may be preserved some time from concreting, and has occasionally been brought to Europe in a liquid state. But even, when thus preserved, a part of it, in the course of time, passes to a solid form. If it could easily be imported in a fluid state, it would be invaluable, from its application to the rendering cloth, leather, and other substances impervious to water.

1. Caoutchouc is inflammable, burning with a bright flame in atmospherical air, and with still greater brilliancy in oxygen gas, or in oxygenized muriatic gas.

2. It is insoluble in water and in alcohol. If long slips of caoutchouc, however, are tied spirally round a glass or metal rod, and boiled for an hour or two, the edges cohere, and a hollow tube is formed.

3. Caoutchouc is soluble in ether ; not, however, in the ordinary state of this fluid as it is found in the shops. To render ether a fit solvent of this substance, it should be purified by washing it with water, in the manner to be hereafter described. The solution may be applied to the purpose of forming tubes or vessels of any shape. The principal difficulty in using it arises from the great volatility of the ether, in consequence of which the brushes, or other instruments, by which it is applied, are soon clogged up, and rendered useless.

4. Caoutchouc is soluble in volatile oils ; but when they have evaporated, they leave it in a glutinous state, and deprived of much of its elasticity. Petroleum dissolves it, and, when evaporated, leaves it unchanged. One of the most useful solvents, however, of caoutchouc, appears to be the *cajeput oil*, a substance lately admitted into the Pharmacopœia of the London College of Physicians. A thick and glutinous solution is obtained, from which alcohol detaches the essential oil. The caoutchouc floats on the surface in a semi-fluid state, but soon hardens, and regains

its elastic powers on exposure to the atmosphere. To this process, the chief objection is the expensiveness of the solvent.

5. Caoutchouc is acted on by alkalis; and, when steeped in them for some time, loses its elasticity.

6. The sulphuric acid is decomposed by it; sulphurous acid is disengaged; and charcoal remains. Nitric acid acts on it with the assistance of heat, nitrous gas is formed; and oxalic acid crystallizes from the residuum.

7. When distilled it gives ammonia, and hence may be inferred to contain azote. A large quantity of olefiant gas and of very dense carburetted hydrogen, which burns with a remarkably bright flame, are at the same time evolved.

SECTION XII.

The Woody Fibre.

AFTER removing all the soluble parts of wood, first by long boiling in water, and then by digestion in alcohol, a fibrous substance is obtained, to which, by some chemists, the name of *Lignin* has been given. From whatever variety of wood it may have been procured, its properties appear to be uniformly the same.

1. It is perfectly destitute of taste, smell, and colour. In specific gravity, it is generally inferior to water.

2. It is insoluble in water at all temperatures.

3. The pure fixed alkalis act on the woody fibre, and render it soft, and of a brown colour.

4. Concentrated sulphuric acid immediately blackens it, and, after sufficient digestion, converts it into charcoal.

5. Nitric acid decomposes it with the assistance of heat: and oxalic, malic, and acetic acids, are formed.

6. When exposed to heat, it affords an acid called the *pyroligneous*, which has been lately proved to be identical with the acetous. This acid holds in combination a quantity of essential oil, from which it can with great difficulty be freed, and also, a small proportion of ammonia. From the last mentioned product, it follows that the woody fibre must contain nitrogen. The charcoal, which remains in the retort, is greatly superior to that procured by the ordinary process; and hence distillation in iron cylinders has been, for some time past, practised as the best method of obtaining charcoal for the manufacture of gun-powder.

6. The woody fibre, by exposure to the atmosphere in a perfectly dry state, does not undergo any change. The action of the

air upon it, however, when moistened, converts it, through various
shades of colour, to a black mould. If the process be carried on
in a confined portion of oxygen gas, carbonic acid is formed.
When excluded from the air, even moist wood shows very little
tendency to decomposition.

SECTION XIII.

Colouring Matter.

I. THE colouring matter of vegetables presents a considerable
variety in its relation to chemical agents, depending on the diver-
sity of the basis, or sub-stratum, in which it resides. Chaptal has
arranged the varieties of the colouring principle under four heads.
1st, As it is attached to extractive matter : 2d, As it resides in
gum ; in both which cases it is soluble in water : 3d, As it exists
in farina, or fecula; and in this instance it dissolves most readily
in sulphuric acid ; 4th, The colouring principle is occasionally
inherent in resin, and then it requires alcohol, an oil, or an alkali,
for solution.

II. The extraction of colouring matter from the various sub-
stances that afford it, and its fixation on wool, silk, or cotton, con-
stitute the art of DYING ; the details of which would be foreign to
the purpose of this work. In this place I shall state only a few
general principles ; and refer for more minute information to a
paper by Mr. Henry in the third volume of the *Manchester Me-
moirs*, and to the works of Berthollet and Bancroft.

III. Of the various colouring substances, used in the art of dy-
ing, some may be permanently attached to the died fabric, and
fully communicate their colour to it, without the intervention of
any other substance ; while others leave a mere stain, removeable
by washing with water. The latter class, however, may be dura-
bly attached by the mediation of what was formerly called a *mor-
daunt*, but has since been more properly termed, by Mr. Henry, a
basis. The colours which are of themselves permanent, have
been termed, by Dr. Bancroft, *substantive* colours ; while those
that require a basis, have been denominated *adjective* colours.

IV. The most important bases, by the mediation of which col-
ouring matter is united with wool or cotton, are alumine, the ox-
ide of iron, and the oxide of tin.—Alumine and oxide of iron are
applied in combination with sulphuric, or acetic acids ; and the
oxide of tin, united with nitro-muriatic, muriatic, acetic, or tarta-
ric acids. In dying, the most common method is to pass the sub-

stance to be died through a decoction of the colouring matter and afterwards through a solution of the basis.—The colouring principle thus becomes permanently fixed on the cloth, sometimes considerably changed by its union with the basis. In calico-printing, the basis, thickened with gum or flour paste, is applied to the cloth by wooden blocks, or copper cylinders. The cloth is then dried, and passed through a decoction of the colouring ingredient, which adheres only to that part of the cloth where the basis has been applied. From the rest of the cloth it may be removed by simple washing with water.

V. The variety of colours, observed in died substances, are reducible to four simples ones, *viz.* blue, red, yellow, and black.

1. Indigo is the only substance used in dying blue, which it does without the intervention of a basis. It is the production, chiefly, of several varieties of the plant called *Indigofera*, a native of America and of the East and West Indies. The plant, after being cut a little while before the time of flowering, is steeped with water in large vats, where it undergoes fermentation. During this process, a fine pulverulent pulp separates, which is at first green, but becomes blue by exposure to the atmosphere. The operations, by which indigo is separated and collected, are rather complicated, and cannot be described without considerable minuteness. A good account of them may be seen in Messrs. Aikin's Chemical Dictionary.

Indigo has been supposed to be a variety of fecula, but it differs from that principle in several important particulars. Water, by being boiled on it, dissolves only about a ninth or a twelfth the weight of the indigo. The colouring matter, however, remains untouched; and the solution, which appears to consist chiefly of extract, has a redish brown hue. It is insoluble in alcohol, ether, and in fixed and volatile oils. Its appropriate solvent appears to be sulphuric acid. When thus dissolved, it is sometimes applied directly, in a diluted state, to the fabric, and dies what is termed a Saxon blue. But, by the abstraction of part of its oxygen, indigo becomes soluble in water; and its colour changes from blue to green. It recovers the former colour, however, on exposure to the air, by again absorbing oxygen. Its de-oxidizement is effected by allowing it to ferment, along with bran, or other vegetable matter; or by decomposing, in contact with it, the green sulphate of iron. Substances died by indigo, thus deprived of oxygen, are green when taken out of the vat, and acquire a blue colour by exposure to the atmosphere. By this revival, the indigo

again becomes insoluble, and fitted, therefore, for affording a per-
manent die.

There appears, however, to be a certain stage of oxigenize-
ment in indigo, which is essential to the existence of its blue col-
our, and that any proportion, either exceeding or falling short of
this, is equally destructive of its colour. Thus diluted nitric acid
dissolves indigo, but the solution is yellow, and the indigo is de-
composed. A thin layer of resinous matter appears, floating in
the solution. If this be removed, and the solution, after evapora-
tion to the consistence of honey, be re-dissolved in hot water, fil-
tered, and mixed with a solution of potash, yellow crystals appear,
which consist of the bitter principle united with potash. These
crystals, being wrapped in paper and struck with a hammer, de-
tonate and emit a purple light.—If to a drachm or two of finely
powdered indigo, we add an ounce measure of fuming nitrous a-
cid, the mixture presently becomes hot, nitrous gas is evolved, a
stream of sparks arises from it, and finally the whole bursts into
flame.

Muriatic acid has no action on indigo, but oxy-muriatic acid de-
stroys its colour. Hence a solution of indigo in sulphuric acid
has been recommended for measuring the strength of watery so-
lutions of oxy-muriatic acid gas ; in order to regulate their ap-
plication to the process of bleaching.

Alkalis do not act on indigo, unless it be previously reduced to
that state of partial dis-oxigenation at which its green colour re-
appears. And the solution exists no longer, if oxygen be absorb-
ed, and the blue colour restored.

The analysis of indigo by destructive distillation affords but lit-
tle information respecting its nature. The products, usually ob-
tained from vegetable substances, are evolved, along with a por-
tion of ammonia.

2. The substances, chiefly employed for affording red colours,
are cochineal (an insect which has been supposed to derive colour
from its food, the leaves of the *cactus opuntia*, L.) archil, madder,
brazil-wood, and saf-flower. The first four are soluble in water ;
the last not without the intervention of an alkali. They are all
adjective colours. Cochineal, though its colour is naturally crim-
son, is used for dying scarlet ; and to evolve the scarlet hue, it is
necessary to employ the super-tartrate of potash. The basis, by
which it is attached to cloth, is the oxide of tin. This may be ex-
hibited experimentally. A decoction of cochineal will leave only
a fugitive stain on a piece of cloth ; but if, in the decoction, some

super-tartrate of potash has been dissolved, and a portion of nitro-muriate of tin afterwards been added, it will impart a permanent scarlet colour.

3. The yellow dies are wild American hiccory, sumach, turmeric, fustic, and quercitron bark; which afford various colours, accordingly as they are combined with the cloth, by the intervention of alumine, or of oxide of iron, or tin. Thus, with the aluminous base, the quercitron bark yields a bright yellow; with oxide of tin, all the shades, from pale lemon colour to a deep orange; and with oxide of iron, a drab colour. With the addition of indigo, it gives a green.

4. A combination of red oxide of iron, with the gallic acid and tan, is the principal black colour, which has therefore the same basis as common writing-ink. In calico-printing, white spots, or figures, on a black ground, are produced, by previously printing on the cloth a protecting paste of citric acid, thickened with gum or flour. The parts to which this paste is applied, do not receive the black die, but remain perfectly white.

VI. The colouring matter of vegetables, besides being capable of fixation on cloth, may be obtained in a dry form, in combination with a base only. Thus if to a decoction, or infusion, of madder in water, a solution of sulphate of alumine be added, the colouring matter is precipitated in combination with the alumine, forming what is termed a *lake*. For obtaining this, the following process is given by Sir H. Englefield. Put two ounces of Dutch crop-madder into a calico bag, capable of holding three or four times that quantity. Pour on it a pint of distilled water, and triturate, in a mortar, as much as can be done, without destroying the bag. The water becomes loaded with colouring matter, and is opake and muddy. Pour off this portion, and repeat the operation till no more colour is obtained, which will generally happen after the fifth or sixth affusion.—Pour these several washings into an earthen or well-tinned copper pan; and apply heat till the liquor boils.—Let it then be poured into a basin; and one ounce of alum, dissolved in a pint of water, be added, and mixed by stirring. Add an ounce and a half of saturated solution of sub-carbonate of potash; a violent effervescence will ensue, and the colouring matter will be precipitated. Stir the mixture till cold, and wash repeatedly with boiling water. About half an ounce of lake will be obtained, containing two fifths its weight of alumine.

Other lakes may be obtained, of different colours, by the substitution of different dying woods; and from the infusion of coch-

ineal, the beautiful pigment called Carmine is precipitated by means of a solution of tin.

SECTION XIV.

Tan, Tannin, or the Tanning Principle.

TAN exists abundantly in the bark of the oak, the willow, &c. and in the gall-nut. The interior bark, next to the wood, contains the largest proportion ; the middle and coloured part, the next ; and in this it is accompanied with more extract. The epidermis affords very little.

I.   Tan may be obtained by any of the following processes; but, according to Mr. Davy, it is difficult to procure it in a state of perfect purity.

1. Into a strong infusion of nut-galls, pour the muriate of tin, till the yellowish precipitate, which at first falls down abundantly, ceases to appear.   Wash the precipitate with a small quantity of distilled water, and afterwards add a sufficient quantity of warm water for its solution.   From this solution, the oxide of tin is precipitated by a stream of sulphuretted hydrogen gas ; and the tannin, which remains dissolved, may be procured by evaporation. There is reason, however, Dr. Bostock informs me, to believe that, by this process, tan is so much altered as to be scarcely entitled to retain the appellation ; and the same remark applies, though perhaps not in an equal degree, to the two following operations.

2. Into a saturated infusion of galls, pour a saturated solution of carbonate of potash.   The yellowish white precipitate, after being washed with a small quantity of water, affords the tan.   When thus prepared, Mr. Davy observes that tan is not perfectly pure, but contains a minute proportion of gallic acid, and alkali.

3. Into a similar infusion, pour sulphuric or muriatic acid.   A precipitate will form, which must be re-dissolved in water, and the excess of sulphuric acid saturated by carbonate of potash. When a farther addition is made of the alkali, the tan falls down, and must be purified by washing with a small quantity of water.

It has been discovered by Mr. Davy, that the terra japonica, or catechu (which is to be met with under this name in the druggists' shops,) is composed of about one half tan, the remainder being a mixture of extract, mucilage, and earthy impurities.   A substance, lately introduced into medicine under the name of Extract of Rhatania, Dr. Bostock is of opinion, consists of tan in a purer form than catechu.

II. Tan has the following properties :

1. When evaporated to dryness, it forms a brown friable mass, which has much resemblance in its fracture to aloes, a sharp bitter taste, and is soluble in water, but still more readily in alcohol.

2. From this watery solution all acids precipitate tan.

3. The alkaline carbonates have a similar effect.

4. The watery solution, poured into one of glue (inspissated animal jelly,) converts it immediately into a coagulum, insoluble by boiling water, which has the elastic properties of the gluten of wheat.

The solution of gelatine, or jelly, may be prepared, for the purpose of precipitating tan, by dissolving ising-glass in water, in the proportion of ten grains to two ounces. The precipitate consists of 54 jelly and 46 tan. An excess of the solution partly re-dissolves it. It is this property, of forming with gelatine an insoluble compound, that fits tan for the purpose of preserving leather.

From Dr. Duncan, jun. who has made numerous experiments on tan, I learn, that the proportion of ingredients in this precipitate varies very considerably, according to the mode in which it is effected ; and that insolubility in water is by no means one of its constant characters. In ammonia it dissolves readily. Dr. Bostock, also, has found that tan and jelly do not unite in any constant proportion, and that the compound is not, in all cases, insoluble in water. (See his paper on the union of Tan and Jelly, Nicholson's Journal, xxiv. 1.)

5. Tan forms, with fecula, or starch, a precipitate which is sparingly soluble in cold water, and very copiously in hot water.

6. With gluten it gives an insoluble precipitate.

7. It is precipitated by salts with earthy bases, such as the nitrates of barytes, lime, &c.

8. It is separated also by salts with metallic bases, such as acetate of lead, muriate of tin, muriate of gold, sulphate of iron, tartarized antimony, and muriate of platina.

Green sulphate of iron effects no change in the solution of tan, but the red sulphate occasions a dark blueish precipitate. This precipitate differs from gallate of iron, in being decomposed by acids, the tan being thus separated. An excess of the red sulphate re-dissolves the precipitate, and affords a black or dark blue liquor. By union with tan, the red sulphate is de-oxidized, the salt becoming the green sulphate, and the oxygen passing to the tan. Tan may also be oxygenized, by passing streams of oxygenized muriatic acid through its solution in water.

Until within the few past years, tan had been known only as a production of nature ; and the processes of chemistry had effected nothing more, than its separation from the various substances, with which it occurs combined.　An important discovery, however, has been made by Mr. Hatchett, of the artificial formation of tan, from substances which unquestionably do not contain it, but only furnish its elements.　The processes for its factitious production are very numerous ; but they are arranged, by their author, under three heads.　1st, The synthesis of tan may be effected by the action of nitric acid on animal or vegetable charcoal ; 2dly, By distilling nitric acid from common resin, indigo, dragon's blood, and various other resinous substances ; 3dly, By the action of sulphuric acid on common resin, elemi, asafœtida, camphor, &c.　Of these various processes, I shall select the most simple, referring to Mr. Hatchett's very interesting paper for a fuller detail of the experiments.　(See Philosophical Transactions for 1805 and 1806.)

To 100 grains of powdered charcoal, contained in a mattras, add an ounce of nitric acid (specific gr. 1.4) diluted with two ounces of water ; place the vessel in a sand-heat, and continue the digestion till the charcoal appears to be dissolved.　A copious discharge of nitrous gas will take place.　At the end of the second day, it may be necessary to add another ounce, and sometimes even a third, of nitric acid ; and to continue the digestion during five or six days.　A redish brown solution will be obtained, which must be evaporated to dryness in a glass vessel ; taking care in the latter part of the process, so to regulate the temperature, that the acid may be expelled, without decomposing the residuum.　A brown glossy substance will be obtained, having a resinous fracture, and amounting, in weight, to 116 or 120 grains.　This substance has the following properties :

1. It is speedily dissolved by cold water and by alcohol.　2. It has an astringent flavour.　3. Exposed to heat, it smokes but little, swells much, and affords a bulky coal.　4. Its solution in water reddens litmus paper.　5. The solution copiously precipitates metallic salts, especially muriate of tin, acetate of lead, and red sulphate of iron.　These precipitates, for the most part, are brown, inclining to chocolate, excepting that of tin, which is blackish grey.　6. Gold is precipitated from its solution in a metallic state.　7. The earthy salts are precipitated by it.　8. Gelatine is instantly precipitated from water, in the state of coagulum, insoluble both in cold and in boiling water.

The identity of this substance with tan can, therefore, be scarcely doubted, since the two bodies agree in having the same characteristic properties. The only essential circumstance of discrimination is, that the natural tan is destroyed, while the artificial is produced, by the agency of nitric acid; and that the artificial substance, even when formed, powerfully resists the decomposing action of this acid, which readily destroys natural tan. Even, however, among the different varieties of the natural substance, Mr. Hatchett found essential differences in the facility of destruction by nitric acid. Those of oak bark and catechu are less destructible; and, in general, the varieties of tan seem to be less permanent, in proportion to the quantity of mucilage which they contain. Infusions of factitious tan differ, also, it has been said, from those of the natural kind, in not becoming mouldy by keeping. This character, however, is not confirmed by Dr. Bostock, who has observed the artificial tan to mould.

The artificial substance is a purer variety of tan than the natural one; inasmuch as it is perfectly free from gallic acid, and from extract, both of which are always present in the latter. The properties of the factitious compound vary a little, according to the mode of its preparation, principally in the colour of the precipitates, which it separates from metallic solutions. Those effected by tan, formed by processes of the first class, are always brown, and by the second, pale or deep yellow.

SECTION XV.

Wax.

It was long supposed that bees' wax is merely the dust of the stamina of plants, unchanged by any process in the economy of that animal. This opinion, however, has been lately shown by Huber (Nicholson's Journal, ix. 182) to be erroneous; for bees, he has proved, continue to form wax, when supplied with only raw sugar or honey. Little doubt, therefore, can exist that sugar contains all the principles of wax; and that wax is the result of a new combination of those principles, effected by the animal.

At the same time, it is equally well established, that wax is also a product of vegetation. It forms the varnish, which is conspicuous on the upper leaves of many trees, and may be extracted by first removing, by water and alcohol from the bruised leaves, every thing that is soluble in those fluids; then macerating the remainder with liquid ammonia, which dissolves the wax, and lets

it fall on the subsequent addition of sulphuric acid. Wax exists, also, in the substance called lac, in combination with colouring matter; and is obtained, in considerable quantity, from the berries of the *Myrica Cerifera*, by the simple process of boiling them in water, and bruising them at the same time. The wax melts and rises to the surface in the form of a scum, which concretes on cooling.*

In its ordinary state, wax of every kind has considerable colour and smell. It may be deprived of both, by exposing it, in thin laminæ, to the action of the light and air, or still more speedily by oxy-muriatic acid gas. When bleached, it has the following properties:

1. Its specific gravity is about .960, water being 1.000. When heated, it melts at about 155° Fahrenheit, or at about 7° higher than unbleached wax, and forms a transparent fluid, which gradually acquires consistency, till at length it returns to a solid state. If the heat be raised, it boils; and a portion distils over. By a still higher heat, it is decomposed, and a quantity of olefiant and hydro-carburet gases are developed. The residuum of charcoal bears only a small proportion to the wax which has been decomposed. From the results of its combustion, Lavoisier has inferred that wax consists of

$$82.28 \text{ carbon}$$
$$17.72 \text{ hydrogen}$$
$$\overline{}$$
$$100$$

2. Wax is insoluble in water.

3. Boiling alcohol dissolves about one twentieth its weight of wax, four fifths of which separate on cooling; and the remainder is immediately precipitated by the addition of water. Boiling ether dissolves about one twentieth of its weight.

4. Caustic fixed alkalis convert it into a saponaceous compound, soluble in warm water. A heated solution of ammonia dissolves it, and forms a kind of emulsion. On cooling the wax rises to the surface in flocculi.

Myrtle wax, it appears from the experiments of Dr. Bostock, differs from bees' wax in being more fusible (*viz.* at 109° Fahrenheit,) and in being soluble, to a greater amount, both in ether and in alcohol.

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* Cadet, *Annales de Chimie*, xliv.

SECTION XVI.

The Bitter Principle.

THE bitter taste of certain vegetables appears to be owing to the presence of a peculiar substance, differing from every other in its chemical properties. It may be extracted from the wood of quassia, the root of gentian, the leaves of the hop, and several other plants, by infusing them for some time in cold water. The characters of this substance have been attentively examined by Dr. Thomson, who enumerates them as follows. (System of Chemistry, v. 95.)

1. When water, thus impregnated, is evaporated, to dryness by a very gentle heat, it leaves a brownish yellow substance, which retains a certain degree of transparency. For some time it continues ductile, but at last becomes brittle. Its taste is intensely bitter.

2. When heated, it softens, swells, and blackens ; then burns away without flaming much ; and leaves a small quantity of ashes.

3. It is very soluble in water, and in alcohol.

4. It does not alter blue vegetable colours.

5. It is not precipitated by the watery solution of lime, barytes, or strontites ; nor is it changed by alkalis.

6. Tincture of galls, infusion of nut-galls, and gallic acid, produce no effect.

7. Of the metallic salts, nitrate of silver and acetate of lead are the only ones that throw it down. The effect of nitrate of silver cannot be ascribed to the presence of muriatic acid, since nitrate of lead produces no change in the solution. The precipitate by acetate of lead is very abundant ; and that salt, therefore, affords the best test for discovering the bitter principle, provided no other substances be present, by which, also, it is decomposed.

From recent experiments of Mr. Hatchett, it appears that the bitter principle is formed, along with tan, by the action of nitric acid on indigo.

Another modification of the bitter principle has been extracted, by Mr. Chenevix, from unroasted coffee. The infusion of the berries was mixed with muriate of tin, when a precipitate appeared, which was well washed, then diffused through water, and decomposed by sulphuretted hydrogen gas, which carried down the tin. The remaining liquid, evaporated to dryness, gave a semi-transparent substance not unlike horn. This substance did not attract moisture from the air ; was soluble in water and alcohol ;

and the solution, on adding alkali, became of a garnet red. Solution of iron gave it a fine green tinge, or, when very concentrated, threw down a green precipitate; and muriate of tin occasioned a yellow sediment. It was not affected by solution of animal gelatine.

The bitter principle may, also, be formed by artificial processes, chiefly by the action of nitric acid on animal and vegetable substances. Welther obtained it by digesting silk with nitric acid; and Mr. Hatchett has formed it from the same acid and indigo. Its colour is a deep yellow, and its taste intensely bitter. It is soluble in water and alcohol, and is susceptible of a regular crystallized form. It unites with alkalis and composes crystallizable salts. Its compound of this substance with potash detonates when struck with a hammer, and inflames like gun-powder when thrown on hot charcoal. On the whole it appears better entitled to rank as a distinct principle, than that which is extracted, by infusion, from vegetables.

SECTION XVII.

Narcotic Principle.*

OPIUM, and other vegetable products possessed of a narcotic power, are composed of several of the vegetable principles, that have already been enumerated. Besides these, however, they contain a peculiar one, in which the narcotic virtue resides.

I. To obtain the narcotic principle from opium, let water be digested upon it, and the strained solution be evaporated to the consistence of syrup. A gritty precipitate will begin to appear, which is considerably increased by diluting the liquid with water. This consists of three distinct substances, resin, oxigenized extract, and the narcotic principle. Boiling alcohol dissolves the resin and narcotic principle only; and the latter falls down in crystals, as the solution cools; still, however, coloured with resin. The crystals may be purified by repeated solutions and crystallizations.

II. 1. The narcotic principle, thus obtained, is white. It crystallizes in rectangular prisms with rhomboidal bases. It is destitute of taste and smell.

2. It is insoluble in cold water, but is soluble in 400 parts of boiling water, from which it precipitates again as the solution

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* I cannot find from conversation with various chemical friends, that the narcotic principle has been obtained separate in this country.

cools.   When thus dissolved, it does not affect vegetable blue colours.

3. It is soluble in 24 parts of boiling alcohol, and in 100 of cold alcohol.   Water precipitates it, in the state of a white powder.

4. Hot ether dissolves, but deposites it on cooling.   When heated in a spoon, it melts like wax.

5. It is soluble in acids, and precipitated by alkalis.   With nitric acid it dissolves, and becomes red; and much oxalic acid is formed, a bitter substance remaining.

6. It may be combined with water and alcohol, by the intervention of resin and extract, the presence of which seems originally to render it soluble in those fluids.

SECTION XVIII.
Suber, and its Acid.

THIS name is used to denote common cork wood, which appears to be possessed of peculiar properties, especially in its relation to nitric acid.

I. To a quantity of cork, grated into powder, and contained in a tubulated retort, add six times its weight of nitric acid, of the specific gravity 1.261; and distil the mixture, with a gentle heat, as long as any red vapours escape.   As the distillation advances, a yellow matter, like wax, appears on the surface of the liquid. While the contents of the retort continue hot, they are to be poured into a glass vessel, placed on a sand-bath, and constantly stirred with a glass rod, by which means the liquid gradually becomes thick.   As soon as white penetrating vapours appear, let it be removed from the sand-bath, and stirred till it becomes cold.   An orange-coloured mass will be obtained, of the consistence of honey, having a strong and sharp odour while hot, and a peculiar aromatic smell when cold.   On this, pour twice its weight of boiling water; apply heat till it liquefies; and filter.   The filtered liquor, as it cools, deposites a powdery sediment, and becomes covered with a thin pellicle.   The sediment is to be separated by filtration; and the liquid reduced, by evaporation, nearly to dryness. This mass is the suberic acid.   It may be purified, either by saturating it with alkali, and precipitating by an acid, or by boiling it with charcoal powder.

II. Suberic acid has the following properties:

1. It is not crystallizable.

2. It has an acid and slightly bitter taste; and, when dissolved in boiling water, it acts on the throat, and excites coughing.

3. It reddens vegetable blues, and changes the blue solution of indigo in sulphuric acid to green.

4. Cold water dissolves about $\frac{1}{150}$th its weight, and boiling water half its weight.

5. It attracts moisture from the air.

6. When heated in a mattras, it sublimes, and is obtained in concentric circles, composed of numerous small points.

7. With alkalis, earths, and metallic oxides, it forms a class of salts called Suberates.

The action of nitric acid on cork, and the properties of the suberic acid and its compounds, have been lately investigated by Chevreul, whose memoir may be consulted in the 23d volume of Nicholson's Journal.

SECTION XIX.

Of Bitumens.

THOUGH bitumens, on account of their origin, are, with more propriety, classed among mineral substances ; yet, in chemical properties, they are more closely allied to the products of the vegetable kingdom.   Like vegetable substances in general, they burn in the open air, and with a degree of brightness that surpasses even that of resins.   By distillation *per se*, they yield a weak acetic acid, an empyreumatic oil, some ammonia, and a considerable quantity of carburetted hydrogen gas, with occasionally a small proportion of carbonic acid and sulphuretted hydrogen.   They are neither soluble in water nor in alcohol, and in the latter respect they differ from resins.   There can be little doubt that they have been formed originally by the decomposition of vegetables.

The bitumens have been divided into liquid and solid.   Formerly it was supposed that the former have been derived, by a sort of natural distillation, from the latter ; but Mr Hatchett has rendered it more probable that the solid bitumens result from the consolidation of the fluid ones.*

The bituminous substances are Naphtha, Petroleum, Mineral Tar, Mineral Pitch, Asphaltum, Jet, Pit-Coal, Bituminous Wood, Turf, and Peat.   To these some writers have added Amber and the Honey-Stone.

NAPHTHA is a substance well known to Mineralogists as a light, thin, often colourless oil, highly odoriferous and inflammable, which is found on the surface of the water of certain springs in

* Linnæan Transactions, 1797.

Italy, and on the shores of the Caspian Sea. It has a penetrating but not disagreeable odour. Its specific gravity is about .708, or according to Brisson .845. It does not congeal at 0° Fahrenheit.

Naphtha is highly inflammable, and burns with a penetrating smell and much smoke. It may be distilled without alteration. By long exposure to the air it becomes thick and coloured, and passes to the state of petroleum. The addition of a little sulphuric or nitric acid produces the same change more speedily. It is not miscible either with water or with alcohol.

Naphtha appears to be the only fluid we are acquainted with, in which oxygen does not exist in considerable proportion. This circumstance renders it of great use in preserving the new metals discovered by Mr. Davy. When recently distilled, they have no action on it; but in naphtha that has been exposed to the air, these metals soon oxidate; and alkali is formed, which unites with the naphtha into a kind of brown soap.

PETROLEUM is considerably thicker than naphtha, and has a greasy feel. It is either wholly or in part transparent, and of a redish brown colour. Its specific gravity is .878.

When distilled *per se*, a portion of colourless naphtha is first obtained; then an empyreumatic acid liquor; next a thick brown oil; and a portion of black shining coal remains in the retort.

Petroleum is highly inflammable. Sulphuric and nitric acids convert it into a thick bitumen; and exposure to the air produces the same effect more slowly. It has the property of combining with fat and essential oils, with resins, camphor, and sulphur; and, when rectified, it dissolves caoutchouc.

MINERAL TAR is thicker and more viscid than petroleum, and of a redish or blackish brown colour. In chemical properties it resembles petroleum.

The solid bitumens are Maltha, Asphaltum, and Elastic Bitumen or Mineral Caoutchouc, beside the several varieties of Coal and Peat.

MALTHA or MINERAL PITCH has a brownish black colour, and little or no lustre. It is so soft that it is impressed by the nails, but does not stain the fingers. Its specific gravity is from 1.45 to 2.06. It is extremely inflammable, and burns with a bright flame, leaving only a small quantity of ashes.

ASPHALTUM is brownish black in its colour, is brittle, shining, and does not stain the fingers. Its specific gravity varies from 1.07 to 1.65. It is extremely inflammable, and burns with a yellow flame. By distillation *per se*, it yields a light brown oil resem-

bling naphtha, a portion of water impregnated with ammonia, and a quantity of carburetted hydrogen gas. It has been analyzed by Klaproth, whose account of it may be seen in the second volume of his " Contributions."

The appropriate solvent of asphaltum is naphtha, of which it requires five times its weight. The solution is of a deep black colour, and forms an excellent varnish.

ELASTIC BITUMEN or MINERAL CAOUTCHOUC is a rare production of nature, and has hitherto been found only in Derbyshire. It is inflammable, and burns with much smoke. By a gentle heat it is melted and converted into petroleum, maltha, or asphaltum. It resists the action of all solvents.

RETINASPHALTUM is also a rare production of the same county. It has no elasticity ; but is brittle and breaks with a glassy fracture. Its colour is pale ochre yellow ; its specific gravity 1.135. It melts on the application of heat, and burns with a bright flame. It is partially soluble in alcohol, potash, and nitric acid. One hundred parts contain 55 resin, 41 asphaltum, and 3 earthy matter.

PIT-COAL is a general term, applied to several distinct varieties of minerals. They have been divided into the three families of brown coal ; black coal ; and glance coal or mineral carbon.

Brown coal is only imperfectly bituminized, and exhibits, distinctly, the remains of the vegetables, from whose decay it has originated. It is brown, opake, somewhat flexible and elastic, and nearly light enough to float on water. It burns with a clear flame, and with a bituminous odour mixed with that of sulphur. In the mode of its combustion, as well as in its external appearance, it bears a considerable resemblance to wood that has been half charred.

Black coal is the substance, which is commonly applied to the purposes of fuel. It shows no remains of the vegetables from which it has originated ; but appears to be a compound of bitumen and charcoal ; and according to the proportion of these two ingredients, its properties vary considerably. The best kinds melt on the application of a moderate heat, and burn almost entirely away, with a clear bright flame. By distillation, they yield a quantity of water holding carbonate and sulphuret of ammonia in solution ; a large proportion of tar is obtained which, by evaporation and fusion, forms a kind of asphaltum ; and an immense production takes place of heavy carburetted hydrogen gas, which may be advantageously applied to burning in lamps. In the retort, a hard heavy charcoal remains called *coak*. It contains gen-

erally a good deal of sulphur; and emits, during combustion, a
suffocating smell of sulphurous acid.

Glance coal appears to consist of almost pure charcoal without
any bitumen, and combined only with a proportion of earth. It
is common in some parts of this kingdom, where it is known by
the name of *stone coal.* It burns with little or no flame; and,
when submitted to distillation, yields no tar, and a carburetted hy-
drogen gas, which, from its inferior density, cannot be advanta-
geously burned in lamps.

In PEAT or TURF, the remains of vegetable organization are
generally very evident: and it consists, indeed, in a great meas-
ure, of fibres of several mosses, with occasionally whole branches,
and even trunks, of various trees. It is extremely inflammable in
the open air; and, when distilled in close vessels, yields products
similar to those of coal. The gas, however, which is evolved, ap-
proaches more in its characters to carbonic oxide than to carbu-
retted hydrogen. In an excellent account of this substance, giv-
en by Mr. Jameson in his Mineralogy of the Shetland Isles, peat
is said to contain the suberic acid. The sulphates of iron, soda,
and magnesia, are, also, occasionally found as ingredients of
peat; and, when in considerable proportion, impair its combusti-
bility.

MELLILITE or HONEY-STONE, so called from the resemblance
of its colour to that of honey, is a very rare production, and has
been found, accompanying brown coal, in a very few parts of the
continent. It is consumed when ignited in the open air, but with-
out flame or smoke. When long boiled in water, it yields a so-
lution, which, on being concentrated and mixed with alcohol, be-
comes pitchy. By continued trituration, however, it is dissolved
with the exception of some earthy flocculi. The clear liquid, de-
canted and evaporated, yields a brownish saline mass; from
which, by two successive evaporations and solutions, needle-shap-
ed crystals are obtained. These are the pure *mellitic acid.*

The taste of this acid is sweetish, and at the same time sour,
with some bitterness. It is combustible when ignited in the air;
and is decomposed by nitric acid, without the production of any
oxalic acid. Dropped into the watery solutions of lime, barytes,
or strontites, it gives a precipitate, which is soluble in muriatic a-
cid. With acetates of barytes and lead, and nitrates of mercury
and iron, it gives precipitates, which are soluble in nitric acid. It
neutralizes the three alkalis, and affords with them crystallizable
salts.

SECTION XX.

Of the Vegetable Principles of Asparagus, Elm-tree Gum, and Elecampane.

BY an attentive examination of the products of vegetation, some new substances have been discovered, the properties of which do not agree with those of any that have been the subjects of the preceding sections. Hitherto, however, they have scarcely been so much investigated, as to entitle them to rank as distinct species.

1. From the juice of asparagus, concentrated by evaporation, Messrs. Vauquelin and Robiquet observed a considerable number of crystals to separate spontaneously.* Of these, some became, after repeated crystallizations, perfectly white and transparent. They were cool and slightly nauseous to the taste; were soluble in water; and neither affected the re-agents for acids nor alkalis. The infusion of galls, acetate of lead, oxalate of ammonia, muriate of barytes, and hydro-sulphuret of potash, produced no change in the solution; and no ammonia was disengaged by potash. When burned in a platina crucible, they swelled up and emitted penetrating vapours, which affected the eyes and nose like the smoke of wood; and left a large proportion of charcoal, in which no traces of alkali could be discovered. Towards the close of the decomposition, an odour arose similar to that of animal matter, and inclining, also, to that of ammonia. It appears, therefore, that this substance, though crystallizable, cannot be considered as a neutral salt; for it contains neither alkali nor earth. Like other vegetable matters it appears to consist of hydrogen, oxygen, and charcoal, in proportions not yet determined, with perhaps some nitrogen.

2. In the year 1802, Klaproth received from Palermo, a substance which exudes spontaneously from a species of elm, and which, in external characters, bore a considerable resemblance to gum. It dissolved in a small quantity of water, and gave a transparent solution of a blackish brown colour, which was not, however, mucilaginous, and could not be applied to the purpose of a paste. Nitric acid precipitated from the solution a light brown substance, which was soluble in alcohol, though the gum itself resisted that solvent. Oxy-muriatic acid produced a similar effect. The property of producing a resin by the addition of a lit-

tle oxygen, is peculiar to this substance, and sufficiently charac-
teristic. Dr. Thomson has proposed for it the name of *Ulmin*.

3. When the roots of the *inula helenium* or elecampane are
boiled some time in water, the decoction, after standing some
hours, deposites a white powder like starch, but differing in its
chemical qualities. Rose, who appears to be the only person that
has investigated its properties, finds* that it is insoluble in cold
water, but readily dissolves in four times its weight of boiling wa-
ter into a liquid which is somewhat mucilaginous and not quite
transparent. After some hours, the substance precipitates from
the water, in the form of a white powder; and it is immediately
thrown down by alcohol. When placed on burning coals, it melts
as readily as sugar, and emits a similar smell. When treated
with nitric acid, it yields oxalic and malic acids; or acetic acid if
too much nitric acid be employed. It differs, however, from gum
in not affording, by this treatment, any saccholactic acid; and
from starch (besides separating spontaneously from hot water,) in
yielding none of the waxy matter, which is formed when starch is
digested with the same acid.

CHAPTER XX.

RESULT OF THE SPONTANEOUS DECOMPOSITION OF VEGETABLE
SUBSTANCES.

SECTION I.

Vinous Fermentation.

THE phenomena and results of this process may be accurately
examined, by means of an apparatus similar to that described in
Lavoisier's Elements, part iii. ch. vi. A more simple one, how-
ever, will sufficiently answer the purpose. It may consist of a
large glass mattras, shaped like that fig. 4, capable of holding 10
or 12 pints. Into the opening of the neck, a glass tube may be
cemented, which is to be twice bent at right angles. The aper-
ture of the other leg may terminate in a two-necked bottle, from
which a bent glass tube is to proceed, and to be carried under the
shelf of the pneumatic trough, or (which is better) into the re-
ceiving-pipe of a gazometer, fig. 35, *b*. The mattras may then
be half filled with a solution of sugar in a proper quantity of wa-
ter, or with an infusion of malt with the addition of a little yeast.

* Thomson's Chemistry, v. 54.

When placed in a room, the temperature of which is not below 60° Fahrenheit, the fermentation soon begins to take place; a brisk motion is observed in the liquid; it becomes turbid, and deposites some impurities, while a frothy scum rises to the surface. When the materials are in large quantity, *viz.* sufficient to fill a cask, a hissing noise is heard in the liquid, and its bulk increases so much, that, if the vessel were full, it now overflows. At the same time, a considerable quantity of gas escapes, and passes, through the bent tube, into the receiver inverted in the pneumatic trough, or into the gazometer. During the process of fermentation, the liquor preserves a higher temperature than that of the surrounding atmosphere. After some days, these appearances gradually decline; and, if the process has been well conducted, and suspended at the proper period, the result is a liquor, not sweet, like that submitted to experiment, but having a vinous taste and smell.

When the gas, contained in the gazometer, is examined, it is found to be carbonic acid, holding in solution something which has a smell like that of the fermented liquor. On submitting the latter to distillation, we obtain a liquid considerably lighter than water, and having a strong spirituous taste. This, when deprived of the water with which it is combined, is alcohol.

SECTION II.

Alcohol.

I. To prepare alcohol, the spirit of wine of the shops may be employed. To a quantity contained in a glass vessel, the subcarbonate of potash, perfectly dry, and heated to about 300°, is to be added; the mixture is to be well shaken; the clear liquor decanted; and this is to be repeated as long as the alkali is moistened by the spirit. When enough has been employed, the next addition will fall to the bottom in a perfectly dry state. The dry muriate of lime may be advantageously used as a substitute for alkali. Or it may be employed to strengthen alcohol, which has been prepared with the mild vegetable alkali. When the salt is no longer moistened on being added to the spirit, we may conclude that enough has been used. Two distinct strata will then be seen in the liquid, the solution of muriate of lime in water, at the bottom, and the alcohol at the top. The latter is to be decanted, or drawn off by a syphon, and then submitted to distillation, reserving only the portions which first pass over.

II. 1. Alcohol is considerably lighter than water, *viz.* in the proportion of 800 or 820 to 1000. The lightest that can be obtained, by simple distillation, from spirit of wine, has the specific gravity of 825. But by the intervention of substances which strongly attract water, Chaussier brought it to the specific gravity of 798, and Lovitz and Saussure jun. to 791 or 792. Alcohol of the specific gravity 820 still contains, according to Lovitz, about $\frac{1}{10}$ its weight of water. When of the specific gravity 920, it has been called *proof spirits* ; the term *above proof* being used to denote a spirit lighter than this, and *under proof* one which contains a still larger proportion of water. Rectified spirit is directed, by the London Pharmacopœia, to have the specific gravity of 835, but it seldom exceeds 840. The quantity of alcohol and water in mixtures of different specific gravities may be learned from Mr. Gilpin's copious tables, of which the following is an abstract.*

TABLE,
Showing the specific Gravity of Mixtures of Alcohol and Water.

Centesimal parts of the Mixture.	SPECIFIC GRAVITIES.	
	According to Chaussier.	According to Gilpin (last Table.)
Alcohol . 100	0.7980	0.825
95	0.8165	0.83887
90	0.8340	0.85244
85	0.8485	0.86414
80	0.8620	0.87606
75	0.87525	0.88762
70	0.8880	0.89883
65	0.9005	0.90941
60	0.9120	0.91981
55	0 9230	0.92961
50	0.9334	0.93882
45	0.94265	0.94726
40	0.9514	0.95493
35	0.95865	0.96158
30	0.96535	0.96736
25	0.97035	0.97239
20	0.97605	0.97723
15	0.9815	0.98213
10	0.9866	0.98737
5	0.99335	0.99327
0	0.99835	1.00000

* Philosophical Transactions, 1794, or Nicholson's Journal, 4to. vol. i. Mr. Gilpin's standard alcohol had the specific gravity of 825, and Chaussier's of 798.

2. Alcohol unites chemically with water; and caloric is evolved during this union. Equal measures of alcohol and water, each at 50° Fahrenheit, give by sudden admixture an elevation of nearly 20° of temperature; and equal measures of proof spirit and water an increase of $9\frac{1}{2}$°. The bulk of the resulting liquid is less also than that of the two before admixture.—Thus a pint of alcohol and a pint of water, when the mixture has cooled to the temperature of the atmosphere, falls considerably short of two pints.

3. Alcohol is highly inflammable. During its combustion, carbonic acid is generated; no charcoal appears; and a quantity of water is produced which exceeds in weight the alcohol employed. An ingenious apparatus, for the purpose of ascertaining this fact, is described in the third part of Lavoisier's Elements, and is represented in the 9th plate to that work, fig. 5. The flame of alcohol acquires a red colour from muriate of lime, a deep blood-red from the muriate of strontites, and a green tinge from boracic acid.

4. Alcohol is a fluid which is remarkably expansible by heat. Dividing the scale between the freezing and boiling points of water into two equal parts, Mr. De Luc has stated that alcohol expands 35 parts for the first 90°, and 45 parts for the second 90°. The strength of his alcohol, however, is described only by the indefinite test of its firing gunpowder. Mr. Dalton found that 1000 parts of alcohol of the specific gravity .817 at 50° Fahrenheit become 1079 parts at 170°. At 110, half way between the two extremes, the alcohol was at 1039, or half a division below the true mean. The more the alcohol is diluted with water, the greater he found the disproportion between the two parts of the scale.

When of the specific gravity .967, answering to 75 *per cent.* water, the ratio of expansion through the first half between 50° and 170°, was to that through the second half as 35 to 45, which is precisely the same as De Luc gives for pure alcohol. In reporting these results no account is taken of the expansion of the glass vessel, and consequently the real expansions may be considered as rather exceeding the apparent ones which have been stated.

5. Alcohol boils at 176°. If water be added, its boiling point is proportionably raised; so that the temperature, at which it boils, is not a bad test of its strength. At this degree of heat, it is converted into a vapour, which may be exploded by passing an electric spark through a mixture of it with oxygen gas.

6. It has never yet been congealed by any degree of artificial cold. Even when diluted with an equal weight of water, it re-

quires a cold of 6° below 0 to congeal it. (See note 38 at the end
of this vol.)

7. Alcohol is a powerful solvent. It dissolves soap; vegetable
extract; sugar; oxalic, camphoric, tartaric, gallic, and benzoic
acids; volatile oils; resins; and balsams. It combines, also,
with sulphur, phosphorus, and the pure alkalis; but not with their
carbonates. Of the class of salts with alkaline, earthy, and metal-
lic bases, alcohol dissolves some copiously, others sparingly, and
others not at all. The proportion, in which some of these are tak-
en up, is stated in the following table by Wenzel, the principal
defect of which is the omission of the specific gravity of the alco-
hol employed.

Two hundred and forty grains of boiling alcohol dissolve of

	Grains
Borate of ammonia	1
Fluate of alumine	1
————— ammonia	1
Muriate of ammonia	17
————— lime	288
————— magnesia	1313
————— potash	5
Nitrate of alumine	240
————— ammonia	214
————— lime	288
————— magnesia	694
————— potash	5
————— soda	23
Oxalate of alumine	7
Tartrate of alumine	7
————— ammonia	7
————— potash	1
Super-tartrate of potash	7
———— oxalate of potash	7

Mr. Kirwan, also, has given us a very useful table, showing the
power of alcohol at different specific gravities to dissolve several
of the neutral salts. The salts were first deprived of their water
of crystallization, and were digested, during three days with alco-
hol, the temperature of which never exceeded 80° Fahrenheit.

	100 grains of alcohol at				
	.900	.872	.848	.834	.817
Sulphate of soda	0	0	0	0	0
——— magnesia	1	1	0	0	0
Nitrate of potash	2.76	I	0	0	0
——— soda	10.5	6		0.38	0
Muriate of potash	4.62	1.66		0.38	0
——— soda	5.8	3.67		0.5	
——— ammonia	7.5	4.75		1.5	
——— magnesia	21.25		23.75	36.25	50
——— barytes	1		0.29	0.18	0.09
——— crystallized	1.56		0.43	0.32	0.06
Acetate of lime	2.4		4.12	4.75	4.88

Some salts, also, when actually dissolved in water, are precipitated by the addition of alcohol. This is the case chiefly with the sulphates, several of which are precipitated immediately, while others are not separated without the application of heat and a few days' repose.

8. Alcohol, when transmitted through a red-hot copper tube is decomposed. The tube is found lined with a very fine light soot resembling lamp-black, and an enormous quantity of carburetted hydrogen gas is evolved, not less, as appears from an experiment of Van Marum, than ten cubic feet by the decomposition of three ounces of alcohol. From the analysis of this gas, Mr. Cruickshank has inferred that in alcohol the carbon is to the hydrogen in the proportion of 4 to 1.[*]

9. In order to determine accurately the composition of alcohol, Lavoisier burned a quantity with very minute attention to the products. The weight of alcohol consumed amounted to 93.5 grains, and 110.32 grains of oxygen were expended in the combustion. The water produced amounted to 106.2 grains, and the carbonic acid to 93.8. From the known quantity of carbon in carbonic acid, and of hydrogen in water, Lavoisier inferred that the alcohol, on which he operated, consisted of

Carbon	- - - - -	28.53
Hydrogen	- - - - -	7.87
Water (existing in the alcohol)	-	63.6

100

Comparing, then, the composition of alcohol with that of sugar (a compound, as has already been stated, of 8 parts hydrogen, 64

oxygen, and 28 carbon,) the same distinguished philosopher was led to the conclusion that, during the vinous fermentation, part of the carbon, by uniting with the oxygen, passes to the state of carbonic acid, and that the remaining carbon, with the hydrogen of the sugar, composes alcohol. If, therefore, it were possible to combine carbonic acid and alcohol, sugar ought to be regenerated.

An analysis of alcohol has lately been executed with considerable skill by Saussure, jun. Two different methods were employed in his experiments. The first consisted in detonating the vapour of alcohol with oxygen gas; and the result was that 100 parts by weight of alcohol are composed of

Carbon - - 42.82
Hydrogen - 15.82
Oxygen - - 41.36
_____
100

In the second series of experiments, he decomposed alcohol by transmitting it through a red-hot porcelain tube ; and afterwards analyzed the evolved gases. By this process, an element was discovered in alcohol, *viz.* a small portion of nitrogen, which had escaped detection by the first set of experiments. The proportions of alcohol, thus approximated, he states at

Carbon - - 43.65
Oxygen - - 37.85
Hydrogen - 14.94
Nitrogen - 3.52
Ashes - - 0.04
_____
100.*

These results, it seems to me probable, are much nearer the true elements of alcohol than those assigned by Lavoisier. In particular, it appears unlikely that alcohol should contain 63 *per cent.* of water; and it is much more reasonable to suppose that the oxygen and hydrogen, discovered in this compound, exist, not in the state of water, but of a quaternary compound with carbon, and nitrogen.

By distillation with the more powerful acids, alcohol undergoes an important change. It is converted into a liquid considerably lighter than alcohol, and much more volatile and inflammable, and miscible only in small proportion with water. This fluid has re-

ceived the generic name of ETHER ; and the peculiar varieties are distinguished by adding the name of the acid, by the intervention of which they have been prepared.

SECTION III.

Ether.

i. To prepare *sulphuric ether*, pour into a retort any quantity of alcohol, and add, at intervals sufficient to allow the mixture to cool after each addition, an equal weight of concentrated sulphuric acid, agitating them together each time, and taking care that the temperature of the mixture does not rise above 120° Fahrenheit. Let the retort be placed in a sand-bath previously heated to 200°, and be connected, by means of an adopter, with a tubulated receiver. To the tubulure of the receiver, a glass tube, twice bent at right angles, may be luted ; and its aperture be immersed in a cup full of water or mercury. The condensible vapour is thus confined ; while the gases that are produced are allowed to escape. The receiver should be kept cool by the application of ice or of moistened cloths. As soon as the materials begin to boil, ether is produced, and passes over into the receiver. The ebullition is to be continued, till white vapours appear in the retort, or a smell of sulphurous acid is perceived ; and the receiver is then to be removed. The liquor, which it contains, will probably have a smell of sulphurous acid. To purify it, a small quantity of black oxide of manganese may be added, and the mixture may be kept in a bottle about 24 hours, agitating it occasionally. The clear liquid is then to be decanted, and distilled in a water bath, till one half has come over. This is to be preserved in a well-closed phial. It will be, to the alcohol employed, as about 1 to 3.

If when the ether ceases to be formed, the receiver be removed, and the heat still continued, sulphurous acid is produces abundantly, and a yellowish liquor, very different from ether, distils over. This may be mixed with a small quantity of liquid potash to correct the sulphurous smell, and then submitted to a heat sufficient to drive off the small proportion of ether. The *oil of wine* remains swimming on the watery liquid.

II. *Nitric ether* may be prepared as follows. To two pints of alcohol, contained in a glass retort, add, by degrees, half a pound of nitric acid ; and, after each addition, cool the materials, by setting the retort in a vessel of cold water. Distil the mixture by a

very cautiously regulated heat, till about a pint and a half have come over. In this state the ether is far from being pure, and must be re-distilled, with the addition of pure potash, preserving only the first half or three fourths that come over.

Thenard prepared nitric ether by the following process. Into a retort, he put equal parts (about 16 oz. of each) of alcohol and nitric acid; and adapted to it in succession, by means of glass tubes, five tall bottles, half filled with a saturated solution of muriate of soda. In the last was a bent tube, opening under a jar, to receive the gas. The bottles were surrounded by a mixture of pounded ice and salt, which was stirred occasionally. To commence the operation, a little fire was applied, but it soon became necessary to extinguish it, and to cool the retort. On the surface of the saline solution, in each of the bottles, was found, after the process was concluded, a yellowish liquid, equal in weight to about half the alcohol employed. That in the first bottle was impure; but the remaining four contained nitric ether free from admixture.

Nitric ether, thus prepared, is specifically lighter than water, but heavier than alcohol. It dissolves in the latter fluid, but requires for solution 48 parts of water. It reddens litmus; and though this property may be destroyed by a little lime, yet the ether soon becomes acid again by keeping. It is highly combustible; and much more volatile than the best sulphuric ether. It is composed, in 100 parts, of 16 azote, 39 carbon, 34 oxygen, and 9 hydrogen. (Nicholson's Journal, xviii. 144.)

III. To prepare *muriatic ether*, add, to a mixture of 8 parts of manganese and 24 of muriate of soda, in a retort, 12 parts of sulphuric acid, previously mixed, with the necessary caution, with 8 of alcohol, and proceed to distillation. The ether, thus obtained, requires to be rectified by a second distillation from potash; and is still liable to be contaminated with sulphuric ether. A more certain process, which is not however, unaccompanied with some difficulty, consists in passing oxigenized muriatic gas through alcohol; and, according to Klaproth, this kind of ether may, also, be safely and effectually prepared by distilling equal parts of alcohol and oxigenized muriate of tin. The distilled liquid is to be rectified by a second distillation with caustic potash. An improved mode of preparing this ether, and an account of its properties, by Thenard, may be found in Nicholson's Journal, xviii. 177, or in the Philosophical Magazine, xxx. 101.

IV. *Phosphoric ether* may be obtained, by distilling a mixture

of thick tenacious phosphoric acid and alcohol. The first product is a portion of unchanged alcohol. After this a liquid passes over, which has an etherial smell, and a specific gravity inferior to that of alcohol. It is very volatile, requires for solution eight or ten parts of water; boils at 100°; and burns with a white flame, without leaving any trace of acid. (See Boullay, *Annales de Chimie*, lxii. 192.)

V. *Fluoric ether* has been obtained by distilling, in a leaden retort, a mixture of equal parts of fluate of lime, sulphuric acid, and alcohol. The product of this distillation was again distilled till one half had come over, to which potash was added. This precipitated so much silex, as to gelatinate the whole mass, which, on being again distilled, gave a light etherial liquid of the specific gravity .720. (Nicholson's Journal, viii. 143.)

VI. *Acetic ether* may be formed by repeatedly distilling concentrated acetic acid (procured from acetate of copper) with alcohol, and returning the distilled liquor to the charge in the retort. The ether, thus produced, may be freed from a redundance of acid, by distillation with a small quantity of potash. It is heavier than other ethers, its specific gravity being .866. It is volatile; boils at 128°, and burns with a yellowish white flame. During combustion, acetic acid is developed, though none can be discovered in the ether before.

This process has been lately repeated with considerable attention by Mr. Chenevix. By repeatedly distilling to dryness a mixture of ten parts of alcohol with ten parts of acetic acid, he ascertained that no change in the specific gravity of the product took place after the first distillation. Seven twelfths of the acetic acid were decomposed. Dry carbonate of potash, added in sufficient quantity to absorb all the water, gave a quantity of etherial liquor, which weighed 7.4 parts, and had the specific gravity of 8.621.[*]

Sulphuric ether will be best employed to exhibit the properties of this substance, which are the following:

1. It is extremely light, having the specific gravity of .730, or, according to Lovitz, even of .632.

2. It does not, like alcohol, combine with water; and when the two fluids are shaken together, they separate again on standing. Water, however, retains about one tenth its weight of ether. By repeated agitation with water, ether is brought to a high degree of purity, and acquires the property of dissolving caoutchouc.

The process, as performed in presence of Faujas St. Fond, by

[*] Annales de Chimie, lxix. 45.

Mr. Winch of London, is described by the former as follows : Let a pint of good sulphuric ether be put into a bottle (or, in preference, into the separator, plate i. fig. 3,) along with two pints of water ; agitate the two liquids repeatedly together ; then let them stand till the ether has risen to the surface ; and draw off the water through the lower cock *b*, leaving the ether in the vessel. Repeat this process three or four times, or till scarcely one third of the ether remains ; and decant the residue into a well-stopped phial.   In this ether the elastic gum, cut into thin slips, soon begins to swell ; but its action is slow, and about the end of five days, the solution is completed.   The method of forming tubes, &c. with this solution, is described in the first volume of Faujas's Travels in England, chap. i.

3. Ether is extremely volatile. A few drops, poured on the hand, evaporate instantly ; and produce a sense of great cold. By pouring a small stream of ether, on a thermometer bulb filled with water, from a capillary tube, the water is frozen, even in a warm summer atmosphere. Under the pressure of the atmosphere, it boils at 98° Fahrenheit, and in vacuo considerably below 32°. Two ounce measures, when converted into gas at the temperature of $72\frac{1}{2}$° Fahrenheit, fill the space of a cubic foot. (Saussure jun.)

4. A mixture of sulphuric and muriatic ethers evaporates instantaneously, and produces a degree of cold considerably below 0 of Fahrenheit.

5. Ether assumes a solid form, by reducing its temperature to —46° Fahrenheit.

6. Ether is converted into a gas, either by raising its temperature, or diminishing the pressure of the atmosphere on its surface. The experiments proving this have already been described, chap. iii. sect. 4.

7. Ether does not dissolve the fixed alkalis, but combines with ammonia.

8. It dissolves essential oils and resins, and takes up about a twentieth of its weight of sulphur, which is deposited as the sulphur volatilizes. Ether dissolves, also, a small portion of phosphorus, and the solution, when poured on the surface of warm water in the dark, emits a lambent blue flame.

9. It is highly inflammable. This is best shown by passing a few drops into a receiver furnished with a brass cap and cock, to which a small pipe is screwed, and inverted in water of the temperature of 100°. The receiver will be filled with the gas of e-

ther, which may be expelled through the pipe and set on fire. It burns with a beautiful deep blue flame.

10. When ether is previously mixed with oxygen gas, it detonates loudly. Into a strong two-ounce phial, filled with oxygen gas, and wrapped round with a cloth, let fall a drop of ether. On applying the flame of a candle, a violent detonation will ensue. Or to a portion of oxygen gas, contained in the detonating tube, fig. 28, pass up a drop or two of ether. The volume of the gas will be doubled ; and, on transmitting an electric spark, a violent detonation will ensue, which will probably shatter the tube. In an experiment of Mr. Cruickshank, three measures of oxygen and one of etherial gas detonated most violently, and $2\frac{1}{3}$ measures of carbonic acid gas were produced.

The following experiment, evincing the inflammability of ether, is described, by Mr. Cruickshank, in Nicholson's Journal, 4to. v. 205 :

Fill a bottle of the capacity of three or four pints, with the pure oxigenized muriatic acid gas, taking care to expel the water as completely as possible. Then throw into it about a drachm or a drachm and a half of good ether, covering its mouth immediately with a pice of light wood or paper. In a few seconds white vapour will be seen moving circularly in the bottle, and this will soon be followed by an explosion, accompanied with flame. At the same time a considerable quantity of carbon will be deposited, and the bottle will be found to contain carbonic acid gas.

The same effect is produced, but more slowly, by alcohol ; and, along with the carbonic acid and carbon, a little ether is produced.

11. According to Mr. Cruickshank, the proportion of carbon to hydrogen is in alcohol as eight or nine to one, and in ether as five to one. (Nicholson's Journal, 4to. v. 205, n.) Mr. Saussure, however, has lately submitted ether to analysis with somewhat different results. By following the same processes as those which have been already described in the section on alcohol, he has determined that 100 parts by weight of sulphuric ether are composed of

Carbon	58.2	or 59
Hydrogen	22.14	— 22
Oxygen	19.66	— 19
	100*	100

These results, compared with the analysis of alcohol by the

* Nicholson's Journal, xxi. 328.

same philosopher, show that ether contains much more carbon and hydrogen, but much less oxygen, than alcohol does. And since two parts of alcohol give one of ether, it will follow that if we take the difference between 200 parts of alcohol and 100 of e-ther produced from it (supposing, also, the two liquids to be re-duced to their ultimate elements,) we shall have a remainder of 100 parts, including

Carbon	-	-	28
Oxygen	-	-	57
Hydrogen		-	8
Nitrogen	-	-	7
			———
			100

It may be observed that the oxygen and hydrogen in the resid-uum are nearly in the proportions that constitute water, or in that of seven to one. We may admit, then, that 100 parts of ether are nearly equal to 200 parts of alcohol, minus 28 parts of carbon and 65 of water, the formation of which has been occasioned by the sulphuric acid.

SECTION IV.

Acetous and Acetic Acids.

THESE two names were applied, by the framers of the new chemical nomenclature, to denote what were supposed to be two distinct acids, common vinegar purified by distillation being term-ed the *acetous*, and the highly concentrated acid formerly called radical vinegar being denominated *acetic*. To account for the superior strength of the latter, it was supposed to hold in combi-nation a larger proportion of oxygen derived from the metallic oxide, from which acetous acid is generally distilled, when con-verted into acetic. The experiments of Adet were the first that threw doubt upon this conclusion; and though they appeared to be contradicted by the subsequent ones of Chaptal and Dabit, yet they received the fullest confirmation from the researches of Dar-racq. The last mentioned chemist succeeded in converting dis-tilled into radical vinegar, under circumstances where no farther oxigenation could possibly be effected, by merely abstracting water from it, by repeated distillation from muriate of lime. Both terms, however, may be retained for the sake of brevity, the *ace-tous acid* denoting the dilute acid obtained by fermentation; and the *acetic*, the acid in its most dephlegmated state.

Acetous acid may be procured by exposing to the atmosphere,

at a temperature between 75° and 90° of Fahrenheit, the liquor
which has been obtained, by the vinous fermentation, from malt,
sugar, or other substances. The liquor soon becomes warm; a
number of ropey filaments appear; and, after several days, it ac-
quires an acid taste and smell. Little or no gas is evolved; but,
on the contrary, an absorption of oxygen takes place. There is
an essential difference, therefore, between the vinous and acetous
fermentations. The latter requires the access of air as an indis-
pensible condition; whereas the vinous fermentation may be per-
formed in close vessels, or at least in vessels which only allow e-
gress to the elastic fluids that are produced.

Common vinegar may be purified, by submitting it to distilla-
tion in a glass retort. The first portion, that comes over, contains
so much water that it may be rejected; and the distillation is to
be stopped, while a quantity of liquid still remains in the retort. In
this way, however, vinegar can only be imperfectly purified. Its
specific gravity is about 1004; and an ounce measure dissolves
about ten grains of powdered marble. The distilled liquor con-
tains an extractive matter, which Darracq considered as mucilage;
and, also, as Mr. Chenevix has shown, a small portion of alcohol.
The extractive matter, it has been found by the latter chemist,
cannot be removed by repeated distillations. In French vinegar,
he discovered a larger proportion both of acid and alcohol, with
less mucilage, than in the vinegar of this country. From four
pints of distilled French vinegar, he obtained nearly an ounce
measure of ardent spirit.

Acetous acid is prepared, also, in very considerable quantity by
the distillation of wood. The wood is inclosed in iron cylinders
or retorts, which are exposed to a red-heat. An immense quanti-
ty of inflammable gas is produced; and a liquid is condensed,
which consists of acetous acid holding in solution a quantity of tar
and of essential oil. These impurities it is scarcely possible to
remove; so that the acid, thus prepared, can be applied only to
the manufacture of solutions for the dier and calico-printer, to
whom its disagreeable smell is not objectionable.

Acetous acid unites with alkalis, earths, and metallic oxides.

When potash, saturated with this acid, is evaporated to dryness,
the salt assumes a black colour. On being re-dissolved, howev-
er, and again evaporated, the salt is obtained white, and, when fus-
ed and suffered to cool, affords the acetate of potash.

This salt strongly attracts moisture from the air, and is very
soluble in water. When exposed to a pretty strong heat it is de-

composed ; carbonic acid and carburetted hydrogen gases come over ; and, in the retort, there remains a mixture of carbon with carbonate of potash.

When this salt is distilled, with half its weight of sulphuric acid, the vegetable acid is expelled in a very concentrated form, mixed with sulphurous acid. Digestion with a small portion of manganese, and subsequent distillation, affords it pure. It may be obtained, also, by distilling equal parts of acetate of lead and sulphate of copper. Or

The crystallized acetate of copper, contained in a glass retort, which may be nearly filled with the salt, may be submitted to distillation in a sand-heat. The acid that comes over has a green colour, and requires to be rectified by a second distillation. Its specific gravity then varies from 1056 to 1080. If the products be reserved in separate portions, it has been observed by M. M. Derosne,[*] that those which are obtained towards the close, though specifically lighter than the earlier ones, are still more powerfully acid, assuming, as the test of their strength, the quantity of alkali which they are capable of saturating. The last products, it was found also, when submitted to distillation, yield a liquid which has even less specific gravity than water. This liquid may be obtained, in a still more perfect state, by saturating the latter portions of acetic acid with caustic and solid potash ; the acetate of potash precipitates ; and a fluid swims above it, which may be rectified by distillation at a gentle heat. It is perfectly limpid ; has a penetrating taste ; is lighter than alcohol ; evaporates rapidly with the production of cold when poured upon the hand ; and is highly inflammable. It does not redden litmus. Excepting that it is miscible, in any proportion, with water, it has all the qualities of ether, and like that fluid has the power of decomposing the nitro-muriate of gold. M. M. Derosne have proposed for it the name of *pyro-acetic ether.* Its production, they observe, is confined to the latter stages in the distillation of acetate of copper, and is owing, they suppose, not to any modification of alcohol, but to changes in the arrangement of the elements of the salt.

These observations are confirmed by the subsequent ones of M. Mollerat.[†] Examining two portions of acetic acid, which had precisely the same specific gravity (*viz.* 1065,) he found that the one contained 87 *per cent.* of real acid, and the other only 41. The first he is disposed to consider as the strongest acetic acid

* *Annales de Chimie*, lxiii. 267.

† *Annales de Chimie*, lxviii. 88 ; or Nicholson's Journal, xxv. 155.

that can be procured. It may be distilled at a very moderate heat with great rapidity, and without entering into ebullition. To this acid, having the specific gravity 1063 (and of which 100 grains required for saturation 250 of sub-carbonate of soda,) he gradually added water, and found, though water is lighter than the acid, yet that the density of the mixture increased till it became 1079. From this point, the additions of water occasioned a regular diminution of specific gravity. Mr. Chenevix has since observed the same anomaly, in the acid produced from acetate of silver.

Acetic acid, thus prepared, has several remarkable properties. Its smell is extremely pungent, and it raises a blister when applied to the skin for a sufficient length of time. When heated in a silver spoon over a lamp, its vapour may be set on fire. At the temperature of about 38° Fahrenheit it becomes solid and shoots into beautiful crystals, which again liquefy at 40°. It appears not to be easily destructible by heat; for Mr. Chenevix transmitted it five times through a red-hot porcelain tube, with the effect of only a partial decomposition.

The acetic acid enters, like vinegar, into combination with alkalis, earths, and metallic oxides.

The ACETATE OF POTASH formed with this acid, is perfectly white; and does not, when liquefied by heat, become blackened by the separation of charcoal, like that afforded by common vinegar. It is deliquescent, and soluble in about its own weight of cold water; and in twice its weight of boiling alcohol. By distillation *per se*, its acid is decomposed and resolved into pyro-acetic ether, carbonic acid, and carburetted hydrogen gases.

ACETATE OF SODA is crystallizable; does not deliquesce in the air; dissolves in less than its own weight of cold water, or in twice its weight of boiling alcohol; and gives, by destructive distillation, similar products to the acetate of potash.

ACETATE OF AMMONIA derives its only importance from being employed in a liquid form in medicine, under the name of *Spirit of Mindererus*. The solution does not yield crystals by evaporation, but affords a deliquescent mass, which is readily soluble in water and in alcohol; and, in its solid form, is volatilized at 250° Fahrenheit.

ACETATE OF LIME may be made, by careful evaporation, to crystallize in the form of small silky needles. It is permanent in the air, and very soluble both in water and alcohol. According to Wenzel, it is composed of 62.3 acid, and 37.7 lime.

ACETATE OF BARYTES is a crystallizable salt, which does not

grow moist, but rather loses a portion of its water, by exposure to the air. It requires for solution about twelve parts of cold, and not quite two parts of boiling water. Alcohol dissolves only a very small proportion. By distillation *per se* Mr. Chénevix finds that it gives pure pyro-acetic ether, of the specific gravity, 0.845, coloured by a little empyreumatic oil.

ACETATE OF STRONTITES is more soluble than the last mentioned acetate, requiring only about twice its weight of cold water for solution. Its properties have not been fully investigated.

ACETATE OF MAGNESIA cannot be obtained in crystals, but only in the state of a thick viscid mass, which is extremely deliquescent, and soluble both in water and alcohol.

ACETATE OF ALUMINE is generally formed, by double decomposition, from the mixed solutions of acetate of lead or lime and sulphate of alumine. It is a compound of considerable importance from its use in dying and calico-printing. When applied, however, to these purposes, it contains always a quantity of common alum, and the properties of the pure combination of alumine with acetous acid are but imperfectly known.

The METALLIC ACETATES have been, for the most part, already described in the history of the individual metals. To our knowledge of this class of salts, some valuable additions have lately been made by a memoir of Mr Chenevix.* By distilling *per se* the different metallic acetates, that excellent chemist found that the salts with bases of lead, zinc, and manganese yield a liquid lighter considerably than water, but heavier than alcohol, and containing only a very small proportion of acid. This degree of levity is owing to the presence of the peculiar fluid, which Derosne has termed pyro-acetic ether, but to which Mr. Chenevix is of opinion, the less definite name of *pyro-acetic spirit* will be better adapted, till we obtain a more accurate knowledge of its nature and properties.

Of all the metallic acetates, that of silver gave a product of the greatest specific gravity, and of greatest power in neutralizing alkalis. In this respect it exceeded, by about one fifth, an equal weight of the acid distilled from copper. It contained, however, none of the pyro-acetic spirit discovered in the acid from copper. The residuum in the retort contained, in every case, a proportion of charcoal. When the acetates of silver, nickel, copper, or lead were distilled, the metal was found in a metallic state ; but zinc and manganese were left in the state of oxides.

* *Annales de Chimie,* lxix ; or Nicholson's Journal, xxvi.

The pyro-acetic spirit, obtained from acetate of lead, Mr. Chenevix describes as perfectly limpid and colourless. It has a taste, which at first is sharp and burning, but afterwards becomes cool and somewhat resinous. Its smell resembles that of volatile oils, but it is not easy to say of which particular one. Its specific gravity, when rectified by muriate of lime, is 7.864. It is very combustible, and leaves no sensible residue. Its boiling point is 138° Fahrenheit. It is miscible in all proportions, with water, with alcohol, and with all the volatile oils, and, at a temperature considerably below its boiling point, with the fixed oils. When heated it dissolves sulphur and wax.

CHAPTER XXI.

ANIMAL SUBSTANCES.

THE products of vegetable and of animal life, though they agree frequently in external characters, and even in some of their chemical relations, present several circumstances of distinction, which, in general, sufficiently discriminate the two classes. Animal substances are the results of still more delicate processes, and of a more refined organization; and the balance of affinities, by which they exist, is disturbed by still slighter causes. To the three great components of vegetable matter (oxygen, hydrogen, and carbon) a fourth is, in animal substances, added, and constitutes a large proportion of their structure. To the nitrogen, which they contain, are owing some of the most important qualities, that distinguish this class of compounds. Hence it is, that instead of passing through the vinous or acetous fermentations; they are peculiarly prone to undergo putrefaction; and that, during this change, they yield, among other products, both nitrogen gas and ammonia. When exposed to a high temperature, ammonia is, also, generated in great abundance, by their decomposition; little or no acetic acid is produced; and the coal, which remains, differs from vegetable charcoal, in being much less combustible. This general description, however, though it applies to most individuals of the animal kingdom, is not strictly true with respect to all. Animal jelly, for example, is rendered sour by spontaneous decomposition. A few vegetable substances, it may also be added, gluten for instance, become at once putrid; and furnish ammonia when decomposed by heat.

In the analysis of animal substances, less precision has been attained, than in that of mineral and vegetable products. It may be considered as of two different kinds. By the first we obtain the *proximate* principles of animal matter, or certain compounds which, we may presume, are separated by the simple processes used for their extraction, in a state identical with that, in which they exist in the animal structure. Thus by the long continued action of hot water on bones, we form a solution, which separates spontaneously into two distinct substances, fat and gelatine; while the earthy ingredients remain undissolved. The substances, thus obtained, are not very numerous; and to distinguish them from more complicated products they may be called *primary animal compounds*. But, by spontaneous decomposition, or by the agency of heat, we give origin to a set of bodies which had no existence in the subject of experiment, the *ultimate elements* of which are thus disunited, and are re-combined in a new manner. Bones, for example, though they contain no volatile alkali, are yet composed, in part, of its elements (nitrogen and hydrogen,) which, at a high temperature, unite and generate ammonia.

The primary animal compounds are not very numerous; the following list comprehending, perhaps, the whole of those which are sufficiently well characterized.

1. Gelátine.
2. Albumen
3. Mucus
4. Fibrin
5. Urea
6. Resin
7. Sugar
8. Oil
9. Acids.

SECTION I.

Animal Jelly, or Gelatine.

ANIMAL jelly is an abundant ingredient not only of the fluids of the body, but of the hard and solid parts. By long continued boiling it may be extracted from the skin, membranes, ligaments, cartilages, and even from the bones. The solution, on cooling, forms a tremulent and imperfectly cohering mass, well known by the name of *jelly*; and, if the watery part of this mass be dissipated by a very gentle heat, we obtain a hard semi-transparent substance, which breaks with a glassy fracture, and, according to the source from which it has been obtained, has the names of isinglass, glue, portable soup, &c.; all of which are varieties of animal gelatine. Isinglass, however, as the purest form under

which gelatine commonly occurs, will be best employed for the exhibition of its chemical properties.

1. Dry gelatine, when immersed in water, gradually absorbs it, swells considerably, and becomes soft and elastic. At common temperatures, however, it is not dissolved; all that is thus effected being the absorption of a quantity of water, which it loses again by a gentle heat. But in hot water it dissolves slowly yet completely; and affords a liquid which again gelatinates on cooling. These alternate solutions and desiccations may be repeated for any number of times, without occasioning any change in the chemical properties of the gelatine, which is submitted to them.

The proportion, in which gelatine forms a solution capable of concreting by cooling, has been determined by Dr. Bostock.* One part of dry gelatine to 100 parts of water gave a solution, that completely stiffened by cooling; but one part of gelatine to 150 parts of water produced a compound, which, though evidently gelatinous, did not assume the concrete form.

2. Gelatine in a solid state seems to be absolutely indestructible when kept in a dry place; but, when in the form of solution or of jelly, it is generally said to become first sour, and afterwards putrid. The production of acid, however, Dr. Bostock informs me, he is disposed to question.

3. Gelatine is insoluble in alcohol, but it is not precipitated, by that fluid, from its watery solution.

4. It readily dissolves in most of the acids. Isinglass, dissolved in common vinegar by the assistance of a gentle heat, forms a very useful and adhesive cement. Nitric acid, even when cold and very dilute, is a powerful solvent of gelatine. When the solution is evaporated, the acid and gelatine re-act upon each other; nitrous gas is disengaged; and, if the concentration be not carried too far, oxalic and malic acids are obtained from the residuum.— Muriatic acid dissolves gelatine, and retains it unchanged in solution.—If oxy-muriatic acid be passed through a solution of gelatine, white filaments appear, which, when collected, are found to be very flexible and elastic. They consist of gelatine, very little altered, and united with muriatic acid and oxy-muriatic acid. They are insipid; insoluble in water and in alcohol; not putrescible; and exert a feeble action on blue vegetable colours, although they contain a large proportion of acid. Exposed to the air during some days, they emit oxy-muriatic acid at common temperatures; and still more abundantly when heated. In alka-

* Nicholson's Journal, xi. and xiv.

line solutions they disappear, and muriatic salts are formed. (Thenard, *Memoires d' Arcueil*, ii.)

5. Gelatine is soluble in pure liquid alkalis. The solution is a brownish viscid substance, which has none of the characters of soap,* and is not precipitated by acids. This is a property which distinguishes gelatine from albumen, fibrin, and other animal products ; and which points out a method of separating it from them in analysis. Owing to the solvent power of alkalis, they do not occasion any precipitation in acid solutions of gelatine ; but when added in excess, dissolve it.

6. Several of the metallic salts and oxides have the property of precipitating gelatine ; but not so unequivocally, as to be good tests of its presence. Goulard's extract of lead (prepared by boiling litharge in distilled vinegar) effects no change in a solution of gelatine. The same may be said of corrosive muriate of mercury. Nitrate of silver and nitro-muriate of tin produce a slight, and almost imperceptible, opacity. The addition of nitro-muriate of gold causes a small quantity of a dense precipitate, from a solution containing $\frac{1}{50}$th of gelatine, but not from more dilute solutions.

7. One of the most active precipitants of jelly is tan. When the proportion of gelatine to water is so small, as to compose only $\frac{1}{5000}$ part of the solution, a considerable precipitate is produced by an infusion of galls (prepared by macerating an ounce of galls in a pint of water.) The stronger the solution of jelly, the more copious is the precipitate ; till at length, when the gelatine is in large proportion, a dense coagulum is formed, which, after being dried in the open air, becomes a hard substance with a vitreous fracture. This compound appears to be equally formed, when animal solids, composed chiefly of gelatine, are immersed in solutions of tan ; as when the skins of animals, for instance, are steeped in an infusion of oak bark. It is perfectly insoluble in water, and incapable of putrefying ; and it constitutes the preservative part of tanned leather, to which it imparts the property of resisting the transmission of moisture. The operation of tanning, then, consists essentially in the attraction of tan, from liquors which contain it, by the gelatine of the skins.

It would have been an important step towards the accuracy of the analysis of animal substances, if we could have ascertained the quantity of gelatine in any fluid, by precipitating it with tan. But to this there are two obstacles. Tan acts, also, on other animal

* Hatchett, Philosophical Transactions, 1800.

fluids; upon albumen for instance. It appears, also, that into the precipitate of tan and jelly, these substances do not enter in absolutely fixed proportions. In general, however, Dr. Bostock has been led to conclude that the compound, formed by the union of jelly and tan, consists of somewhat less than two parts of tan to three of gelatine. And as we always have it in our power to ascertain what quantity of tan is employed in precipitating any solution of jelly, we may, by an easy calculation, approximate the quantity of jelly, contained in the fluid we are examining.

8. The decomposition of gelatine into its ultimate elements by heat gives us little more information, than that it is chiefly composed of oxygen, hydrogen, carbon, and nitrogen; but in what proportions they exist, or in what manner they are combined, we are still ignorant. After incineration, a coal remains, which contains a minute proportion of phosphate of soda and phosphate of lime.

We are not acquainted with those circumstances, that occasion the differences in the several kinds of animal gelatine. Some valuable remarks on them may be found in Mr. Hatchett's "Observations on the component Parts of Animal Membrane." (Philosophical Transactions, 1800.)

SECTION II.

Albumen.

WITH the exception of gelatine, no fluid appears to enter so largely into the composition of animal substances, as albumen. It forms a large proportion of the blood and of various secretions; and appears to be the chief basis of several of the solids; *viz.* of the thin membrane which constitutes the cellular texture, as well as of the skin, glands, and vessels that convey the fluids.

The white of an egg, though not composed of absolutely pure albumen, contains it sufficiently so for the exhibition of its properties. These will be found to be the following:

1. By agitation with water, the two fluids unite, and form a viscid liquid, the component parts of which do not separate by standing. This solution gives a green tinge to vegetable blue colours; a proof of the presence of uncombined alkali.

2. At the temperature of 160° Fahrenheit undiluted albumen becomes solid, a change which is called its *coagulation.* When the solid mass is cut into slices, and suffered to remain for some hours, a few drops of a brownish viscid fluid ooze out, amounting

to about $4\frac{1}{2}$ grains from 100 of the original albumen submitted to experiment. By a long continued gentle heat, the coagulated substance itself loses at least four fifths of its weight; and the solid matter is left behind, in the form of a hard brittle transparent substance. Hence it will follow, that 100 grains of the white of egg consist of 80 grains of water, $4\frac{1}{2}$ uncoagulable matter, and only $15\frac{1}{2}$ of pure albumen.

Coagulation by heat is the distinguishing character of albumen, and affords an easy and obvious test of its presence; even when it forms a very minute proportion of certain fluids. By adding it, in gradually diminished quantity, to water, Dr. Bostock found that a solution, containing only $\frac{1}{1000}$ its weight of albumen, was rendered perceptibly opake by a boiling temperature. For all practical purposes, therefore, this may be considered as a sufficiently accurate test of its presence in any fluid.

The uncoagulated part of the white of egg, Dr. Bostock found, was not affected by muriate of mercury, or by infusion of galls; but was copiously precipitated by Goulard's extract of lead. He considers it as a peculiar fluid to which he has given the name of *mucus*.

Albumen, which has been coagulated by heat, though perfectly insoluble in water, unless by long boiling aided by a Papin's digestor, appears to have undergone no change in its chemical constitution. During coagulation, there is no absorption of oxygen; no gas is extricated; and hence there appears to be no re-action of the principles of the compound on each other. The coagulum is taken up by dilute liquid alkalis with a disengagement of ammonia. From this combination it is precipitated, unchanged, by acids.[*] By long boiling in water, however, though no apparent solution takes place, Mr. Brande obtained, from coagulated albumen, a fluid which had alkaline properties; and which gave, after evaporation, a viscid substance soluble in water. This fluid he apprehends to be a dilute solution of albumen in alkali.[†]

3. Albumen is coagulated by alcohol, and by acids. The coagulum, formed by the latter, always retains in combination, according to Thenard, a portion of the acid which has been employed. That produced by nitric acid is least soluble; and hence nitric acid occasions a precipitate from solutions of albumen, which are so dilute as not to be affected by other acids. The coagulum, produced by acids, is re-dissolved by pure alkalis, even, as Then-

[*] Thenard, *Annales de Chimie*, lxvii. 321.
[†] Philosophical Transactions, 1809.

ard finds, by ammonia, which does not dissolve albumen that has been coagulated by heat.

Alum, probably in consequence of its excess of acid, coagulates albumen; but does not act on very dilute solutions. One part in 500 of water is rendered slightly turbid by a solution of alum; but no precipitate is formed.

4. Albumen is coagulated by several of the metallic salts. Solution of corrosive muriate of mercury, which has no effect on gelatine or mucus, is a delicate test of the presence of albumen. A single drop of the solution, added to a liquor containing $\frac{1}{1000}$ its weight of albumen, renders it visibly milky; and, at the end of some hours, a flocculent precipitate falls to the bottom of the vessel. The same re-agent produces a sensible effect on a liquid, containing only half that quantity, or $\frac{1}{2000}$ of albumen.

Solution of corrosive sublimate, however, does no separate the whole of the albumen unless heat is employed. The precipitate is a compound of the metallic salt with albumen, in the proportion of about one of the former to three or four of the latter. From the quantity of corrosive sublimate, therefore, required to decompose entirely a solution of albumen, we may infer the quantity of the latter; for three grains of the metallic salt, being entirely decomposed, indicate $10\frac{1}{2}$ grains of albumen.

Nitro-muriate of tin precipitates albumen, but less actively than the foregoing salt. Water, holding $\frac{1}{500}$ of albumen, was not altered by this test, till after some hours, when it became milky. Nitrate of silver occasions a precipitate; but the effect is equivocal, from its precipitating, also, the muriate of soda.—Nitro-muriate of gold throws down a dense precipitate from a solution containing $\frac{1}{1000}$ of albumen. Goulard's extract occasions an abundant dense coagulum.

5. Solutions of albumen are decomposed by the addition of tan. When an infusion of galls, containing $2\frac{1}{2}$ parts of solid extract in 100, is added to a liquor, of which albumen forms only $\frac{1}{1000}$ part, no immediate effect is apparent; but, after some time, a precipitate ensues. If infusion of tan be poured into a concentrated solution of albumen, the precipitate has the consistence of pitch; is not susceptible of putrefaction; and, when dry, is brittle like over-tanned leather.

6. Albumen, in whatever way it has been coagulated, appears to be slow in undergoing putrefaction. Mr. Hatchett kept it for some weeks under water, without any tendency to that state. According to Scheele, a small portion of coagulated albumen is so-

luble in dilute acids, and precipitable by the same acids when concentrated. By steeping albumen, for a month, in dilute nitric acid, Mr. Hatchett converted it into a substance, which was soluble in water, and affected chemical tests like gelatine.

Many theories had been formed of the cause of the coagulation of albumen; but the first probable conjecture on the subject appears to have originated with Dr. Thomson.* The fluidity of albumen he supposed to depend on the presence of alkaline matter, and its coagulation on the removal of the alkali, or its saturation with some other substance. This suggestion has been confirmed by some recent and well devised experiments of Mr. Brande.† When the white of an egg was exposed to the action of a galvanic battery, a rapid and abundant coagulation took place round the negative pole, while a thin film only collected at the positive wire. This more copious precipitation at the negative pole appears to have been owing to the separation of alkali; and as it required, in order to produce the effect, a comparatively high electrical power, it should follow that the *rapid* abstraction of alkali is necessary to the perfect coagulation of albumen.

White of egg, then, is a compound of albumen with alkali and water. When heat is applied, the alkali is transferred to the water, and the albumen becomes insoluble. The alkaline liquor, which is thus produced, re-acts upon and dissolves a small quantity of coagulated albumen. When alcohol or acids are the coagulating powers, the effect is owing to a like transfer of alkali.

When the uncoagulable part of white of egg was exposed to a strong galvanic power, uncombined soda was found in the negative cup; and muriatic acid with a little coagulated albumen in the positive one. Hence fluid albumen contains both free soda and muriate of soda. In the experiments of Mr. Hatchett, 500 grains of dry albumen afforded $74\frac{1}{2}$ of coal, of which $11\frac{1}{4}$ were saline matter, composed, besides the salts that have been mentioned, of phosphate of lime and of phosphate and carbonate of soda.

From the researches of Mr. Brande it appears that galvanism may be applied to the discovery of very minute quantities of albumen, which are not rendered sensible by any other test. In this way he produced a rapid coagulation, at the negative pole, in several animal fluids, in which albumen had not been supposed to exist. It has been found, also, by Mr. Home, that albumen is coagulated by galvanic arrangements of too low a power to affect even

* System of Chemistry, v. 489.
† Philosophical Transactions, 1809.

even the most delicate electrometer ; and hence he has proposed albuminous fluids as tests of the presence of small quantities of electricity.*

SECTION III.

Mucus.

THE term mucus had been employed in a vague and general sense, until Mr. Hatchett, in his valuable paper on the component parts of animal membrane,† attempted to assign to it a more definite meaning. Jelly and mucus he coesiders as modifications of the same substance, and as not essentially differing from each other. The latter term he restricts to that animal substance, which is soluble in cold water, and which cannot be brought to assume the gelatinous state. Dr. Bostock, however, has endeavoured to prove that mucus is a distinct fluid, characterized by a train of properties, which are entirely different from those of animal gelatine.‡ Fourcroy and Vauquelin have admitted, also, its claim to be considered as a peculiar compound.§ They apply the term, in an enlarged sense, to the viscid liquor, which lubricates the mouth, the œsophagus, the stomach, the intestines, and, in general, all the cavities and passages of the body. It differs, they suppose, from vegetable gum, in nothing but in containing a proportion of nitrogen. In the descriptions of its characters, however, they are much less precise than either of the English chemists.

The substance on which Dr. Bostock's experiments were made, was the saliva of the mouth, dissolved in water by agitation. No appearance of coagulation was produced by raising the temperature of this liquid to 212°, nor, when the liquid was evaporated, and suffered to cool, did it show any tendency to gelatinate.

No distinct effect was produced on the solution of mucus, by adding nitro-muriate of tin, muriate of mercury, or infusion of galls. Goulard's extract occasioned an immediate opacity, and, after some time, a flaky precipitate. Hence the effects, produced by the tanning principle and by Goulard's extract, establish a decided and essential difference between mucus and gelatine. Tan is a most delicate test of gelatine ; but does not, in any degree, affect mucus. Goulard, again, is a sensible test of mucus, but not of jelly. Corrosive muriate of mercury, on the contrary,

* Philosophical Transactions, 1809.   † Ditto, 1800.
‡ Nicholson's Journal, xi. and xiv.   § *Annales de Chimie.* lxvii.

which discovers very small proportions of albumen, is not affected by either jelly or mucus.

Hitherto, however, Dr. Bostock has not been able to devise a a method of determining, exactly, the proportion of mucus in any compound fluid. One great obstacle to all attempts of this kind is, that mucus, besides animal matter, appears always to contain common salt, which acts upon the tests; so that it is impossible to say, how much of the effect is owing to each of these separate causes. The precipitates, thrown down from mucus by acetate of lead and nitrate of silver, Mr Brande has found to consist both of the muriates and phosphates of those metals. From 1000 grains of saliva, he obtained 120 grains of dry residuum, of which twenty grains were saline matter. The proportion of salts, in the mucus of the trachea, was even still greater. This variety of mucus, was not coagulated either by heat, by alcohol, or by acids.

In order to obtain mucus free from neutral salts, it occurred to Mr. Brande to attempt their decomposition by electricity. With this view, a mixture of saliva and water was placed in a vessel intermediate between two others, which contained water only (see i. fig. 82,) and which were connected, the one with the positive, the other with the negative, extremity of a galvanic apparatus. Fibres of cotton connected the central vessel with the two others. In about ten minutes, a considerable quantity of white coagulum was formed upon the cotton on the negative side; but none on the positive. Thus albumen appears to be a constituent part of saliva, though not discoverable by the usual tests. A separation of alkali took place on the negative side; and hence Mr. Brande is disposed to consider mucus as a compound of albumen and muriate of soda, or of albumen and of pure soda. The whole of this subject, however, is still obscure; and requires to be illustrated by farther experiments.

When mucus is evaporated to dryness by a gentle heat, no material change is produced in it. The result is a semi-transparent substance resembling gum, and, like it, soluble again in cold water. Neither alcohol nor ether dissolve it. By destructive distillation, it yields only the common elements of animal matter.

SECTION IV.

Fibrin, or Animal Gluten.

FIBRIN forms the basis of the muscular or fleshy parts of animals, and remains, combined with albumen, when all the soluble

parts have been washed away by water. It may also be obtained from blood, by laying the coagulum on a linen strainer and pouring water upon it, till a white fibrous matter alone remains.

For the purpose of submitting fibrin to a series of experiments, Mr. Hatchett obtained it by digesting shreds of lean beef, during 15 days, in water, which was changed daily, the temperature being such as not to excite putrefaction. The shreds of muscle were then boiled for five hours every day, during three weeks, changing the water at each boiling; and, finally the residue was put into a press, and dried by the heat of a water bath.

Fibrin has the following characters.

1. It has a white colour, and is destitute of taste and smell. It is soft and elastic, and becomes of a deeper colour, on drying.

2. It undergoes no change, when exposed to the air in a moist state; nor is it altered by being kept under water.

3. When heated, it contracts, and moves like a slip of horn, exhaling at the same time a smell of burning feathers. Exposed to a stronger heat in close vessels, it yields water, carbonate of ammonia, a thick heavy fetid oil, and carbonic acid, and hydro-carburet gases.—It leaves a larger proportion of charcoal, than remains after the decomposition either of gelatine or albumen.

4. It is insoluble in water, except by the heat of a Papin's digestor, and also in alcohol, ether, and oils.

5. It is readily soluble in acids. Sulphuric acid dissolves it and acquires a deep-brown colour; charcoal is precipitated, and acetic acid is formed. Muriatic acid converts it into a green jelly. Acetic, citric, oxalic, and tartaric acids, dissolve it; and the solutions, when concentrated, assume the appearance of jelly.

6. From acid solutions, alkalis precipitate fibrin, in flakes, which are soluble in hot water, and which resemble gelatine in properties.

7. Diluted nitric acid separates a larger quantity of nitrogen gas from fibrin, than from any other animal substance. The dissolved portion, when concentrated by evaporation, and again dissolved in hot water, is precipitated by tan and nitro-muriate of tin, and possesses, therefore, the appropriate characters of gelatine. A larger digestion of fibrin in diluted nitric acid converts part of it into a kind of fatty matter, which swims on the surface. This concrete oil contains a considerable redundance of acid, from which it may be freed, by melting it, once or twice, in water. From the residuary nitric acid a proportion of oxalic acid may be separated by evaporation.

8. Concentrated solutions of potash and soda dissolve fibrin, evolve ammonia, and afford a compound resembling soap.

From a comparison of their properties it appears, then, that fibrin and albumen bear, in several respects, a considerable resemblance to each other. The nitric solution of both has the characteristic qualities of gelatine. From that of fibrin, however, ammonia, added in excess, precipitates oxalate and phosphate of lime, the latter of which pre-existed in the fibrin; while the oxalic acid is a product of the operation. Water, also, which has been boiled on fibrin, contains, besides gelatine, a quantity of phosphate of soda, and even phosphate of lime. Lime, therefore, exists in fibrin, both in the state of phosphate, and in some other state, in which it is capable of uniting with oxalic acid, probably in that of carbonate. Much difference, however, appears to exist as to the proportion of earthy salts, in the fibrin of animals of various ages. Thus veal was found, in Mr. Hatchett's experiments, to give hardly any oxalate of lime, and much less phosphate, than was obtained from beef.

SECTION V.

Urea.

I. UREA may be obtained by the following process.—Evaporate, by a very gentle heat, a portion of human urine, voided six or eight hours after a meal, to the consistence of a thick syrup. In this state it concretes, on cooling, into a crystalline mass. Pour on this, at different times, four times its weight of alcohol, and apply a gentle heat, which will effect the solution of the greater portion. Decant the alcoholic solution, and distil it by a water bath, till it acquires the consistence of syrup, which is to be poured out of the retort. On cooling, it forms a crystallized substance, which is the urea.

II. 1. Urea has the form of crystalline plates, crossing each other in various directions. It has a yellowish white colour; a smell somewhat like that of garlic; is viscid, and difficult to cut; and has an acrid strong taste. It deliquiates, when exposed to the air, into a thick brown liquid. It is extremely soluble in water, and absorbs caloric during solution. Alcohol dissolves it readily, but in less proportion than water; and the alcoholic solution yields crystals more readily than the watery one.

2. The concentrated solution of urea in water yields, on the addition of nitric acid, a copious precipitate of bright pearl-coloured

crystals, resembling the boracic acid. No other acid produces this singular effect.

3. The concentrated solution of urea, in water, is brown; but becomes yellow, when largely diluted. Infusion of galls gives it a yellowish brown colour, but causes no precipitate; nor is it precipitated by infusion of tan.

4. When heat is applied to urea, it melts, swells, and evaporates, with an insufferably fetid smell. By distillation, it yields above two thirds its weight of carbonate of ammonia; about one fourth of benzoic acid; besides carburetted hydrogen, and a residuum composed of charcoal with muriates of soda and ammonia.

5. The solution of urea, in water, putrefies, and is slowly decomposed; but much more rapidly, if a little gelatine be added. Ammonia and acetic acid are the products of its decomposition. If the solution, instead of being left to putrefy, be kept in a boiling temperature, and fresh water be added as the evaporation goes on, the urea is at length wholly decomposed. The condensed vapour is found to contain carbonate of ammonia; acetic acid is formed; and a portion of charcoal remains in the fluid contents of the retort. It has been ascertained, by those who distil the volatile alkali from urine, in manufacturing processes, that an equal quantity of ammonia is obtained whether the urine has undergone putrefaction or not.

6. When a mixture of urea, with one fourth its weight of diluted sulphuric acid is distilled, a quantity of oil appears on the surface, which concretes by cooling; acetic acid passes over into the receiver; and sulphate of ammonia remains in the retort. The repetition of this process converts the whole of a portion of urea into ammonia and acetic acid.

7. Nitric acid acts rapidly on urea; nitrous, azotic, and carbonic acid gases, are disengaged; and prussic acid and ammonia are generated. The residuum, when dried and ignited, detonates like nitrate of ammonia.

8. Muriatic acid dissolves urea without alteration. When a stream of oxymuriatic acid gas is passed through a solution of urea, the gas is rapidly absorbed; and white flakes are formed, which soon assume a brown colour. After the solution has become saturated with gas, the effervescence still continues; and carbonic acid and nitrogen gases are evolved. The residuary liquid contains both carbonic and muriate of ammonia.

9. Urea is soluble in alkaline solutions; and, at the same time, undergoes a partial decomposition. A strong smell of ammonia

arises, probably from the action of the potash on the muriate of ammonia which is contained in urea. When solid potash, however, is triturated with urea, the disengagement of ammonia, is too great to be explained in this way; and can only be accounted for, by supposing the volatile alkali to be formed by the union of its elements. A strong solution of potash, heated with urea, produces a similar effect; a large quantity of ammonia is generated; the residuum diluted with water effervesces violently from the escape of carbonic acid gas; a flocculent precipitate is formed, which has the qualities of a concrete oil; and the liquor, when distilled, gives both acetic and benzoic acids.

10. Urea has the property of changing the form of the crystals of muriate of soda; a solution of that salt, mixed with one of urea, affording, on evaporation, octohedral crystals. Muriate of ammonia, on the contrary, which usually crystallizes in octohedrons, has the form of its crystals altered by similar treatment, to that of cubes.

Of all the animal fluids, then, urea appears most readily to under go decomposition, both from spontaneous changes in the arrangement of its elements and from the action of other substances, From a careful examination of the products of its distillation. Fourcroy and Vauquelin have given the following as the proportions of its elements, which are to be considered, however, as no more than approximations. One hundred parts consist of

Oxygen	39.5
Nitrogen	32.5
Carbon	14.7
Hydrogen	13.3
	———
	100

SECTION VI.

Animal Resins.

THE properties of animal resins have not been fully investigated; but, so far as they have hitherto been examined, they appear to differ considerably from those of the vegetable kingdom.

The RESIN OF BILE may be obtained by the following process:—To 32 parts of recent ox bile, add one of concentrated muriatic acid. When the mixture has stood some hours, strain it, in order to separate a white coagulated substance. Pour the filtered liquor, which has a fine green colour, into a glass vessel, and evaporare by a gentle heat. At a certain point of concentra-

tion, a green sediment falls down, which, after being separated from the liquid part, and washed, affords resin.

1. The resin of bile has a dark brown colour; but, if spread out fine, on a white ground, it exhibits a bright grass-green. It is intensely bitter.

2. At about 122° it melts, and in a high temperature burns rapidly. It is soluble both in cold and hot water, and still more soluble in alcohol, from which it is in part precipitated by water.

3. With pure alkalis it combines, and forms a compound, which has been compared to soap. From these it is precipitated un-changed by acids.

4. When farther oxigenized, by adding oxymuriatic acid to bile, the resinous portion has its properties considerably altered; it ac-quires the colour and consistence of tallow; melts at 104°; and dissolves in alcohol and in hot water.

Besides this resin, there are several animal substances which possess similar qualities. Such are the ear-wax, ambergris, cas-tor, &c.; for an account of which the reader may consult the fifth volume of Thomson's Chemistry.

SECTION VII.

Animal Sugar.

Sugar enters pretty largely into the composition of milk; and into the urine, when altered by disease. It may be obtained from milk by the following process:

I. Let whey be evaporated to the consistence of honey, and al-lowed to cool. It concretes into a solid mass, which is to be dis-solved in water, clarified by white of eggs, filtered, and again e-vaporated to the consistence of syrup. On cooling, a number of brilliant white crystals are deposited, which are the sugar of milk.

1. Sugar of milk has a sweetish taste, and no smell.

2. It requires for solution, seven parts of cold or four of boiling water; and is insoluble in alcohol. In these properties it differs from common sugar, and also in its relation to nitric acid, which will be afterwards stated, under the head of saccholactic acid.

3. When exposed to heat, it melts and burns with the same ap-pearances as sugar, and with a similar smell.

II. The urine of diabetic patients yields sugar on evaporation, which approaches more nearly in its characters to those of veget-able sugar, but is generally said to be incapable of crystallization. By exposing the solution, however, for some time to the air, and

removing occasionally the scum which is formed, I have obtained beautiful white crystals, not inferior to those of vegetable sugar.

SECTION VIII.

Animal Oils.

ANIMAL oils differ from the vegetable oils, in being generally solid at the temperature of the atmosphere, but are similar to them in other properties. Among animal oils, may be ranked butter, tallow, lard, suet, spermaceti, &c.

I. SPERMACETI bears some resemblance to wax, but differs from it in other properties. It is more readily fusible, *viz.* at 112° Fahrenheit; and is less soluble in boiling alcohol, of which it requires 150 times its weight. It is copiously dissolved by boiling ether; and the solution, on cooling, becomes a solid mass. Pure potash acts on it more remarkably than on wax; and the compound is quite soluble. A heated solution of ammonia affords a liquid, which is not precipitated by cooling, or by the addition of water; but is decomposed by acids.

II. A singular instance of the production of animal oil from the lean or muscular part of animals, is presented by the conversion of muscle into a substance resembling spermaceti, and called by the French chemists ADIPOCIRE. To effect this conversion, it is only necessary to confine the fleshy part of an animal in a box, with several holes in it, under the surface of a running stream. When thus confined, the change takes place spontaneously in the course of a few months. But it may be accomplished much sooner, by digesting animal muscle in strong nitric acid, and washing off the acid by water, as soon as the change has ensued. The substance, thus obtained, may be bleached, by exposure to the oxigenized muriatic acid gas.

Adipocire has a light yellow colour, the consistence of tallow, and a homogeneous texture. It melts at an inferior temperature to either of the foregoing bodies, *viz.* at 92° Fahrenheit. Cold alcohol has little action, but when heated, dissolves about $\frac{1}{4}$ or $\frac{1}{3}$ its weight. On cooling, it is deposited nearly white, and the alcohol has acquired a yellow tinge. Boiling ether dissolves nearly one fourth, which separates, almost white, on cooling. Fixed alkalis act on this substance, as on wax and spermaceti. Cold ammonia scarcely attracts it, and in this respect it differs from both the preceding substances.

III. The FAT of animals may be separated from the membra-

nous and other substances, with which it is united, by melting it with a gentle heat, and with the addition of a small quantity of water. Fat, which has been thus prepared, is called *lard* when of a soft consistence, and *tallow* when harder. From the whale and some other animals, the fat is obtained fluid, and is then called animal oil.

Animal fat is insipid and free from smell. It cannot be combined either with water or with alcohol; but it unites with alkalis and forms soap. It is apt to become rancid by keeping, owing to the formation of an acid, most probably by the oxigenation of gelatine, or of some other animal substance which the fat contains.

Fat melts at a very moderate heat. Lard becomes fluid at about 92° Fahrenheit, and tallow a few degrees higher. At a still higher temperature, it is decomposed, and yields, among other products, a large quantity of olefiant gas. Hence its fitness for artificial illumination.

If fat be melted with about one sixteenth its weight of nitric acid, the mixture being kept fluid, and constantly stirred for some time, a considerable change is produced in its appearance. Nitric oxide and nitrogen gases are evolved; and the lard becomes granular, of a firmer consistence, and soluble in alcohol. Any adhering acid may be removed by washing it with water. In this state, it has been called by the French chemists *oxigenated fat*.

Melted fat dissolves both sulphur and phosphorus. It unites, also, with several metallic oxides, and forms compounds, which have nearly a solid consistence.

SECTION IX.

Animal Acids.

OF the acids, that have hitherto been discovered to enter into the composition of animal substances, several have already been described, *viz*. the phosphoric, sulphuric, muriatic, carbonic, benzoic, acetic, and malic. Besides these, the following are either component parts of animal substances, or are formed by treating them with chemical agents.

I. The *uric acid*, or *lithic acid*, exists in human urine, even in its most healthy state. The substance, occasionally voided along with the urine, and called gravel, consists for the most part of uric acid; and this acid forms, also, one of the most common ingredients of urinary calculi.

1. Uric acid, when pure, is destitute of colour, taste, and

smell; it dissolves in 1720 parts of cold water, or in 1150 parts of boiling water; from which, on cooling, much of the acid precipitates. The solution reddens vegetable blue colours, and combines readily with pure alkalis, but does not effervesce with the alkaline carbonates. Fixed alkaline solutions dissolve a considerable quantity of uric acid, if the alkali be in excess. The saturated compounds, however, of uric acid with alkalis, termed urates, are not much more soluble than the acid itself. The combination of uric acid with soda, constitutes the principal part of the concretions found near the joints of gouty persons.

2. Nitric acid dissolves the uric acid, and the solution stains the skin of a pink colour. If the solution be boiled, carbonic acid and nitrogen gases escape, and the prussic acid is formed. On evaporation to dryness, a bright red mass remains. By repeatedly distilling nitric from uric acid, the latter is at length wholly decomposed; carbonic acid and nitrogen gases are evolved; and a strong smell of prussic acid is produced. The residuary fluid deposites crystals, which Dr. Pearson found to be nitrate of ammonia. Oxy-muriatic acid occasions the formation of muriate of ammonia, and of oxalic and malic acids.

3. When the uric acid is distilled *per se*, about one fourth its weight of a yellow sublimate arises, which contains no uric acid; but a new and peculiar one combined with ammonia. A few drops of thick oil make their appearance; and carbonate of ammonia, with some prussic acid, water, and carbonic acid, are obtained. In the retort there remains about one sixth of charcoal.

II. There is a substance well known to physicians, as a deposite from the urine at certain stages of fever, and in other diseases, under the name of lateritious sediment.—According to Proust, this sediment contains, mixed with uric acid and phosphate of lime, a peculiar acid, which he terms the *rosacic*, from its resemblance in colour to that of the rose. This acid, he observes, differs chiefly from the uric, in being very soluble in hot water; in having little tendency to crystallize; and in precipitating muriate of gold of a violet colour. It does not appear, however, that its properties have been hitherto investigated by any other chemist; and its existence may be considered, at present, as in some degree questionable.

III. The *amniotic acid* has been discovered by Fourcroy and Vauquelin, in the liquor of the amnios of the cow, from which, by slow evaporation, it separates in white crystals. It has a brilliant appearance; a slight degree of sourness; reddens vegetable

blues; is scarcely soluble in cold water, but readily in hot, from which it separates, on cooling, in long crystals. It is also soluble in heated alcohol. It combines readily with alkalis and forms neutral salts, from which the amniotic acid is precipitated by other acids. It does not decompose alkaline carbonates; nor does it precipitate salts with earthy bases, nor the nitrates of silver, mercury, or lead. By a strong heat, it is decomposed, emits ammonia and prussic acid, and leaves a bulky charcoal.

IV. The *lactic acid* forms a component part of sour milk; from which the acid may be obtained by gently evaporating it to about one eighth; filtering to separate the curd; and adding lime-water to the residue. An earthy precipitate is formed; and the lime combines with the acid, from which it may be precipitated by oxalic acid. The lactic acid is thus obtained in an impure state, dissolved in water. Evaporate the solution to the consistence of honey; on this pour alcohol, and filter the solution. When the alcohol is separated by distillation, the lactic acid remains pure.

This acid has a yellow colour, is not susceptible of being crystallized, and attracts the humidity of the air. It combines with alkalis and earths, and forms deliquescent salts. It dissolves iron and zinc, with a production of hydrogen gas. It unites also with the oxides of other metals. In its properties, it bears most resemblance to acetic acid. Recent experiments, indeed, have proved that it is really the acetic acid, holding in solution a quantity of extractive matter and of the salts contained in whey, which disguise its ordinary properties. (Nicholson's Journal, x. 264.)

V. The *saccholactic acid* is formed by pouring on powdered sugar of milk, in a stoppered retort, four times its weight of nitric acid, and distilling off a considerable portion of the liquor. On leaving it to crystallize, oxalic acid is obtained; but if, instead of this, the liquid be suddenly diluted with water, a white sediment forms, which may be separated by decantation and washing.

It may, also, be obtained by pouring on one part of gum arabic in a stoppered retort, two parts of nitric acid; applying heat a short time, till a little nitrous and carbonic acid gases have come over, and then allowing the mixture to cool. A white powder gradually separates, from which the liquor is to be decanted. The powder after being washed several times with cold water, is saccholactic acid.

This acid is about one fourth more soluble in hot than in cold water. Of the former it requires 60 parts. The solution is acid,

and reddens the colour of litmus. At a boiling heat, it effervesces with alkaline carbonates; and unites readily with alkalis and earths, forming a genus of salts which are called *saccholactates*. With potash, it affords a salt soluble in eight times its weight of cold water, and crystallizable on cooling; and with soda a salt equally soluble, and requiring only five parts of water for solution.

The saccholactic acid is decomposed, when distilled at a red-heat, and yields an acid liquor, which deposites needle-shaped crystals. An empyreumatic oil is also formed, and a considerable quantity of carbonic acid and hydro-carburet gases. A considerable proportion of charcoal remains in the retort.

VI. The *sebacic acid* may be obtained from various species of animal fat. The simplest process for separating it is that of Guyton. To hogs' lard, melted in an iron kettle, add pulverized quicklime, and stir the mixture for a few minutes, raising the heat towards the end of the process. When cold, the lard will be found to have less solidity. Pour on it a large quantity of water; boil them together, and filter the liquid. A brown acid salt will separate on cooling, consisting of lime, united with sebacic acid. This salt is contaminated with an admixture of oil, from which it may be separated by a degree of heat barely sufficient to decompose the oil. Re-dissolve and crystallize the residue; and, when again dry, distil it with one third its weight of sulphuric acid, diluted with water. Its purity from the latter acid may be ascertained by its affording, with a solution of acetate of lead, a precipitate soluble in nitric acid.

1. The sebacic acid is liquid, white, and has a penetrating smell. It reddens vegetable colours.

2. By distillation it becomes yellow, gives carbonic acid, and is partly decomposed.

3. It unites with alkalis; and, when mingled with nitric acid, dissolves gold.

4. Nitrate and acetate of lead give a precipitate, soluble in acetic acid. It decomposes the muriate of mercury.

According to Thenard, the acid which has been described is merely acetic acid, disguised by a little sulphurous acid. Besides this, however, there is a different acid not before observed, and which is really sebacic acid. It may be obtained by first distilling hogs' lard, and washing the product with hot water. The watery solution, poured into one of acetate of lead, gives a flaky precipitate, which is to be heated, along with sulphuric acid, in a retort. No acid is distilled over; but on the surface of the matter in the

retort, there floats a substance resembling fat, which may be sep-
arated, and washed with boiling water. The water entirely dis-
solves it, and becomes concrete on cooling.

The sebacic acid, thus procured, has a white colour; is with-
out smell; has a slightly acid taste, and reddens infusion of lit-
mus. When heated, it melts like a sort of fat; boiling water
saturated with it becomes solid on cooling. Alcohol dissolves it
copiously. It precipitates acetates and nitrates of mercury and
lead, and nitrate of silver. The alkalis are neutralized by it, and
form soluble salts, which do not decompose the solutions of lime,
barytes, or strontites. It may be volatilized; but requires a high-
er temperature than benzoic acid, which, in several particulars,
it resembles.

VII. The *prussic acid* is formed, chiefly, during the decompo-
sition of animal substances, at high temperatures. Three parts
of blood, evaporated to dryness in an iron dish are to be mixed
with one part of sub-carbonate of potash (common pearlash,) and
calcined in a crucible, which should be only two thirds filled by
the materials, and loosely covered with a lid. The calcination
must be continued with a moderate heat, as long as a blue flame
issues from the crucible; and when it becomes faint, and likely
to be extinguished, the process must be stopped. Throw the
mass, when cold, into 10 or 12 parts of water; allow it to soak a
few hours; and then boil them together in an iron kettle. Filter
the liquor, and continue pouring hot water on the mass, as long
as it acquires any taste.—To this solution, add another, composed
of two parts of alum and one of sulphate of iron, in 8 or 10 of boil-
ing water: and continue the mixture as long as any effervescence
or precipitation ensues. Wash the precipitate several times with
boiling water. It will have a green colour; but, on the addition
of a quantity of muriatic acid, equal in weight to twice that of the
sulphate of iron which has been used, it will assume a beautiful
blue colour. Wash it again with water, and dry it in a gentle
heat. In this state it is the pigment called Prussian blue, which
consists of a mixture of prussiate of iron, with alumine.—Its pro-
perties have already been described. (Chap. xviii. sect. 8, v.

From prussiate of iron, the prussic acid may be separated by
the following process, invented by Scheele.

Mix two ounces of red oxide of mercury, prepared by nitric
acid, with four ounces of finely powdered Prussian blue, and boil
the mixture with twelve ounces of water in a glass vessel, shak-
ing frequently. Filter the solution, which is a prussiate of mer-

cury, while hot; and, when cool, add to it, in a bottle, two ounces of iron filings, and six or seven drachms of sulphuric acid; shake these together, decant the clear liquor into a retort, and distil off one fourth of the liquor.

The distilled liquor is the prussic acid, which has a peculiar smell, a sweet taste, and does not, like other acids, redden vege‑table blue colours, but combines with alkalis and earths.

Prussic acid has the following properties:

1. It has a sweetish taste, and a smell resembling that of bitter almonds.

2. It does not redden blue vegetable colours.

3. It precipitates sulphurets, and curdles soap.

4. It separates alumine from nitric acid. Oxigenized muriatic acid entirely decomposes it.

5. It does not appear to have a strong affinity for alkalis; nor does it take them from carbonic acid; for no effervescence arises on adding it to a solution of alkaline carbonates. On the contrary, its combinations with alkalis and earths are decomposed by ex‑posure to carbonic acid, even when highly diluted, as in atmos‑pheric air. It readily combines, however, with pure alkalis; de‑stroys their alkaline properties, and forms crystallizable salts.

6. It does not precipitate iron blue, but green; and this green precipitate is soluble in acids. The rays of light render the green precipitate blue; as do also the addition of metallic iron, or sul‑phurous acid.

VIII. The *zoonic acid* has been shown by Thenard to be mere‑ly the acetous, holding some animal matter in solution. The *for‑mic* acid, or acid of ants, was submitted to a course of experiments by Fourcroy and Vauquelin, who inferred that it is merely a mix‑ture of acetic and malic acids. This conclusion was opposed by the experiments of Suersen, who endeavoured to prove that the formic is really a peculiar acid; but its identity with the acetic has since been sufficiently established. (*Annales de Chimie*, lxiv. 48.)

CHAPTER XXII.

OF THE MORE COMPLEX ANIMAL PRODUCTS.

ALL arrangements of the various substances, that compose the animal body, must, in the present state of our knowledge, be en‑tirely arbitrary; and it can, therefore, be of little consequence

which of them is adopted. The most obvious division is that which distributes them into fluids and solids, and this order I shall follow in the description of their individual properties. A minute history, however, of all the variety of animal compounds would be foreign to the purpose of this work, and could not be given without very long details. For this reason, I shall notice, at greatest length, those, which are most interesting from their connection with animal physiology.

SECTION I.

Of the Blood—Respiration, &c.

THE blood, when examined as soon as it has been drawn from the body, is a smooth and apparently homogeneous fluid; viscid to the touch; and of a specific gravity exceeding that of water, in the proportion of from 1053 or 1126 to 1000. A vapour presently exhales from it, which has a peculiar smell, but which does not, when condensed, afford a liquid differing essentially from water. In a few minutes, a thin film appears on the surface; and, after a short time, the whole mass becomes coherent. When it has remained some time in this gelatinous state, a more complete separation of its principles ensues. Drops of a yellowish liquid ooze out from beneath the surface of the mass; and, at length, the whole is resolved into two parts, a firm red substance called the cruor, crassamentum, or clot; and a yellowish liquid termed serum. The proportion of these parts varies considerably; the crassamentum being much more abundant in vigorous well fed animals, than in such as have been debilitated by disease or by poor living.

The period, at which coagulation begins, varies not only with the condition of the blood itself, but with the circumstances in which it is placed. It commences sooner as the vessel is more shallow; but, on an average, it may be said to begin in about $3\frac{1}{2}$ minutes, and to be completed in seven. Fourcroy states that, during coagulation, caloric is evolved; but this fact does not appear to be sufficiently ascertained.

The *serum* is an apparently homogeneous fluid, with a yellowish and sometimes slightly greenish tinge; is unctuous to the touch and saltish to the taste. Its specific gravity is about 1027. When exposed to a heat of 160°, and still more readily in that of 212°, serum is converted into a pretty firm white mass. This, in fact, is merely coagulated albumen, the properties of which have

been already described. When cut into slices, and subjected to gentle pressure, a small quantity of a saline liquor may be obtained from it, which is called the *serosity*. This fluid has generally been considered as holding gelatine in solution ; but Dr. Bostock has found reason to doubt the accuracy of the conclusion, and to suspect that it is rather mucus. Besides animal matter, it contains several neutral salts, *viz.* uncombined soda, muriate and phosphate of soda, and phosphate of lime. The pure soda imparts to the serosity the property of changing vegetable blues to green.

The crassamentum or clot is resolvable into two parts, *viz.* what has been called coagulable lymph or *fibrin*, and *red globules*. The separation may be accomplished by long continued washing with water, which dissolves the red globules only, and leaves the fibrin. Its properties differ scarcely at all from those of fibrin obtained by the long boiling of muscular flesh ; but they are essentially distinct from those of coagulated albumen, as will appear from the account which has been already given of the characters of each.

Fibrin, as it is contained in the blood, is held in a state of solution ; and it is still a question to what cause its spontaneous coagulation is owing. That it does not arise from the absorption of oxygen, is plain from the fact that blood, by exposure to oxygen gas, has its coagulation retarded. Hydrogen gas, also, delays its coagulation ; but carbonic acid, nitrous, and nitrogen gases accelerate it. *In vacuo*, Mr. Hunter states that it occurs at the usual period ; but it is not easy to conceive under what circumstances such an experiment could be fairly made. When intercepted in a living vessel, as by placing ligatures on a vein, Mr. Hewson found that blood remained imperfectly fluid for several hours. That mere rest is not sufficient to produce its coagulation appears, also, from the fact, that the blood continues fluid in cases where the circulation is suspended throughout the whole system ; as in fainting, and in suffocation from drowning and other causes. The coagulability of fibrin is destroyed, also, without our being able to explain the fact, in animals killed by electricity and lightning ; by a blow on the stomach ; by the poison of the viper ; or by violent passions of the mind. In some diseases, on the contrary, its tendency to coagulation is greatly increased.

The red globules of the blood (that part to which its peculiar colour is owing) were first attentively observed and accurately described by Mr. Hewson. As their name imports, they have a globular figure, which is sufficiently visible with the aid of the mi-

croscope. They readily dissolve in water, and tinge it with their own peculiar colour; and are soluble, also, in alkalis, acids, and alcohol, but not in the serum. The watery solution turns syrup of violets green; and, after some time, deposites a flocculent precipitate, doubtless from the coagulation of albumen, the presence of which is indicated, also, by the effect of boiling the solution. It appears to consist of albumen, dissolved by an excess of pure soda. When evaporated and calcined in a crucible, a residuum is obtained, amounting to about $\frac{4}{1000}$ of the weight of solid matter, and composed, according to Fourcroy and Vauquelin, chiefly of sub-phosphate of iron. To the iron which blood contains, its red colour has been ascribed, but in all probability without sufficient reason.

It is doubtless on the red globules of the blood that the different gases act, which produce such remarkable changes in the colour of the entire fluid. Nitrogen gas blackens arterial blood, and, according to Girtanner, venous blood also. In an experiment of Dr. Priestly, it appeared that the bulk of a quantity of nitrogen gas, to which arterial blood was exposed, sustained a diminution. Blood, which has had its colour thus impaired, it was found by the same philosopher, may be restored to its bright florid hue, by agitation with oxygen gas; and these changes may, at pleasure, be repeated alternately. Oxygen gas, to which blood is exposed, is diminished in volume, and contaminated by carbonic acid. Atmospheric air undergoes the same change in consequence of the oxygen which it contains, but in a less remarkable degree.

Similar alterations are, also, constantly going on in the blood, during its circulation through the living body. In the veins it is of a dark red colour, inclining to purple. In this state it arives at the right ventricle of the heart, by the contraction of which it is driven into the pulmonary artery. This artery is distributed, by extremely minute ramifications, over the whole surface of the air-cells of the lungs; and, in these, the blood is exposed to the action of atmospherical air, through the slender coats of the blood vessels. Here it acquires a bright vermillion colour; and, returning to the left ventricle of the heart by the pulmonary veins, it is distributed, by the contraction of this ventricle, through the whole body. In its course, it loses its florid colour, and, after traversing the system, returns to the lungs, to be once more fitted for the performance of its functions.

The function of respiration consists of two distinct actions, that of *inspiration*, by which the air is drawn into the lungs; and that

of *expiration*, by which it is expelled, after having served the purpose for which it was inhaled. By an easy natural inspiration, about twenty cubic inches may, perhaps, on an average, be the quantity taken in. It appears, also, from the recent experiments of Messrs. Allen and Pepys,[*] that the same quantity is expired, with little if any diminution. Atmospheric air, after being once only admitted into the lungs, returns charged with 8 or $8\frac{1}{2}$ *per cent.* of carbonic acid gas. If the same portion be breathed repeatedly, considerable uneasiness is experienced ; but the quantity of carbonic acid cannot be increased beyond 10 *per cent.* When the state of the expired air is examined by eudiometrical tests, a quantity of oxygen is found to have disappeared, equal in volume, according to the experiments of the same accurate chemists, to the carbonic acid which has been formed. Now as carbonic acid has been proved to contain exactly its own bulk of oxygen gas, it follows that all the oxygen, which disappears in respiration, must have been expended in forming this acid ; and that no portion of it has united with hydrogen to form water. It may still, however, be doubted, whether the oxygen is absorbed through the coats of the vessels, and displaces carbonic acid, which may be supposed to have pre-existed in the blood ; or whether this acid be not rather generated by the union of the inspired oxygen with the carbon of that fluid. Of the two suppositions, the latter appears to be the most probable.

The only change, then, that has been satisfactorily proved to take place in respired atmospherical air, is the removal of a certain quantity of oxygen (its nitrogen being wholly untouched,) and the substitution of a precisely equal volume of carbonic acid gas. When, however, pure oxygen gas is respired, Messrs. Allen and Pepys have found that it cannot all be traced into this combination ; but that a portion of oxygen has disappeared, and has been replaced by a corresponding quantity of nitrogen [†] The addition of nitrogen appears to be made also, when a mixture of hydrogen and oxygen gases is breathed, in which the latter is in the same proportion as in atmospherical air. This mixture, it was found, may be respired for an hour without inconvenience. The substitution of nitrogen for the oxygen originally inhaled is a fact of considerable importance, and in the present state of our knowledge altogether inexplicable.

Besides carbonic acid, a portion of watery vapour is emitted

[*] Philosophical Transactions, 1808.
[†] Philosophical Transactions, 1809.

from the lungs, and in a quantity sufficient to be visible when the atmosphere is of a low temperature. From various experiments, it may be inferred to amount to about three grains in a minute. Until lately the water, thus exhaled, was supposed to be generated in the lungs, by the union of the inspired oxygen with the hydrogen of the blood; but this hypothesis is inconsistent with the experiments of Messrs. Allen and Pepys, which have traced the whole of the oxygen into combination with carbon. It is probably therefore nothing more than the condensed vapour of a portion of that fluid, which is ordinarily secreted into the bronchial cells.

An important purpose of the function of respiration is, that it contributes to that equable temperature, which the animal body preserves, amidst all the changes in the surrounding medium. This is peculiarly the property of living matter; for all other bodies have the same degree of heat with the substances that are in contact with them. In the human body, the temperature varies only a very few degrees from 96°, whether it be exposed to a cold of many degrees below the freezing point; or whether it be surrounded by an atmosphere, little short of the heat of boiling water. There must, then, be certain processes in the animal economy, by which, in the former case, caloric is reduced from a latent form to that of temperature; and, in the latter case, by which the great excess of caloric is absorbed, and prevented from becoming injurious by its accumulation.

Though we are ignorant of those precise differences, which constitute the distinction between venous and arterial blood, or in what way the function of respiration converts the former into the latter, yet a fact of considerable importance, on this subject, has been discovered by Dr. Crawford. The capacity of arterial blood for caloric he found to be superior to that of venous blood, in the proportion of 1030 to 892. When, therefore, arterial blood is converted into venous, a considerable quantity of caloric must pass from a latent to a free state, and must prove an abundant source of temperature. Now this is precisely what is constantly taking place in the body. Caloric is evolved by the combination of the inspired oxygen with carbon; but as the capacity of blood for caloric is, at the same time, enlarged, its temperature is not raised by being thus arterialized. In its progress through the system, the blood again suffers a diminution of capacity; and the caloric, which it had carried in a latent form to the remotest extremities, is extricated, and applied to the support of animal tem-

perature. This theory explains why the heat is not excessive in the lungs, but is equally distributed over the whole body. In animals, placed in a high temperature, Dr. Crawford has added the important fact, that the change of arterial into venous blood does not go on; and no addition of temperature is, therefore, derived from this source. Another cause, limiting the heat of the body under such circumstances, is the excessive evaporation which takes place from the surface of the skin, and which is indicated by a loss of weight of no inconsiderable amount. (See Nicholson's Journal, xvii. 215.)

It is not in the lungs only that the blood exerts an action on atmospherical air; for a similar function, it appears, belongs to the skin throughout the whole body. If the hand be confined in a portion of atmospherical air or oxygen gas, it has been ascertained that the oxygen disappears, and is replaced by a portion of carbonic acid. At the same time, a considerable quantity of watery fluid transpires, and may be collected by a proper apparatus.

The blood is subservient to various important uses in the animal economy. It is a source, from which are constantly prepared a variety of other substances, both solid and fluid, that are essential to our well being, and even to our existence. From the blood is derived the solid matter of the bones themselves. The muscles, which are affixed to the bones, and which, acting as levers, enable us to change our situation at pleasure, are referable to the same source; and so also is all the variety of animal fluids, which perform a necessary part in the economy of this complicated machine. The solids and fluids, thus produced, are sometimes elaborated by complicated organs called glands, and are then termed *secretions*. A sufficiently exact and comprehensive knowledge of the business of secretion would have been attained, if we were able to discover, in the secreted solids or fluids, substances analogous to those which are found in the blood, and no others. But in many secretions we find principles bearing no resemblance to albumen, gelatine, fibrin, or any of those fluids that form the proximate elements of the blood. In these cases, nature must have gone farther in the work of separation; and, after disuniting the ultimate principles of the blood, have re-combined them in a new manner and in different proportions. This is a species of synthesis, which we have hitherto not been able to imitate in substances of the animal kingdom, and in very few instances even in vegetable products.

SECTION II.

Of the Secretions subservient to Digestion ; viz. the Saliva, the Gastric and Pancreatic Juices, and the Bile.

SALIVA is a liquid secreted by certain glands, and poured into the mouth, for the purpose of being mixed with the food during mastication. It is a slightly viscid liquor, of a saltish taste, destitute of smell, and of a white colour or with a slight tinge of blue. Its specific gravity according to Haller is as 1960 to 1875, or, according to Siebold, as 1080 to 1000. The latter author has compared its consistence to that of a solution of one part of gum in forty parts of water. It is neither acid nor alkaline, and has therefore no effect on blue vegetable colours. Its quantity varies considerably. Nuck has estimated it at eight or ten ounces daily ; and, during a mercurial salivation, several pints flow in the same interval.*

Saliva, when evaporated by a gentle heat to dryness, yields only a very small proportion of dry extract in thin semi-transparent plates ; or, if the process be stopped when about a third only remains, crystals of muriate of soda are formed. Exposed to the air, it appears to absorb oxygen, and becomes of a thicker consistence, whitish flocculi at the same time separating from it.

There is some difficulty in effecting the diffusion of saliva through water ; but this may be accomplished by rubbing the two fluids together in a mortar. The solution, which is thus obtained, was subjected to the action of tests by Dr. Bostock.† Oxymuriate of mercury produced no immediate effect ; but, after some hours, a light flocculent coagulum separated, leaving the liquid nearly transparent. The same test produced a still less striking effect in the filtered portion of some saliva, which had been several days exposed to the atmosphere. Infusion of galls precipitated white flakes, from the recent but not from the filtered liquor. The filtered fluid was copiously precipitated by Goulard's extract, and by nitro-muriate of tin. From these experiments, Dr. Bostock infers, that saliva contains coagulated albumen, and also a quantity of mucus and muriate of soda, but no gelatine. To the quantities of each, he considers the following as an approximation :

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* Fourcroy, *Systeme*, 4to. v. 268.   † Nicholson's Journal, xiv. 147.

Water - - - - 80
Coagulated albumen - - 8
Mucus - - - - 11
Saline substances - - 1

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100

When exposed to the agency of galvanic electricity, Mr. Brande has found that saliva, even after being first boiled in water, gives an abundant coagulation, and a separation of alkali round the negative pole, though neither acids, nor any of the common agents, showed the presence of albumen. Hence it appears that this substance may form part of an animal fluid, and yet not be discoverable by the common tests. In saliva Mr. Brande supposes that it is united with an alkali (probably soda) which, in this state of combination, loses its property of affecting vegetable colours.*

The GASTRIC JUICE is a fluid which is poured out upon the inner surface of the stomach, and is possessed of very extraordinary powers as a solvent. One of the great obstacles to an accurate analysis of it is the difficulty of procuring it sufficiently pure, and free from admixture with the contents of the stomach. It has been generally collected from animals, which have been kept, for some time before being killed, without food. In this state, it is a transparent liquor, having a saline and somewhat bitter taste, and containing neither uncombined acid nor alkali. It precipitates nitrate of silver; and, when evaporated, gives a solid residuum, which is deliquescent, and has an unpleasant smell. By the action of acids, a small proportion of albumen is discovered in it, and gelatine or mucus remains in solution.

This imperfect account of the properties of the gastric juice affords, however, no explanation of the solvent power, which it exerts on all animal and vegetable substances. Even out of the body, it appears, from the experiments of Spallanzani, to retard the putrefaction of animal substances, and to reduce them to a state somewhat similar to that, in which they are found after having been sometime in the stomach. On substances taken into that organ its solvent power is even still more remarkable. In Dr. Stevens's experiment, hollow silver spheres, perforated with small holes and containing animal and vegetable food, were swallowed by a man who possessed the faculty of doing this without injury, and with the result that the food was always dissolved,

* Philosophical Transactions, 1809.

and the vessel voided in an empty state. After death, it appears from the observations of Mr. Hunter, that the stomach itself is sometimes eroded by the gastric juice, large holes having been found in it from the action of that fluid. These facts, as well as the power of the gastric juice in coagulating milk, are quite inexplicable on any known principle.

The PANCREATIC JUICE has not been examined with any attention. The only observations, which we possess respecting it, are those of Dr. Fordyce. He found it to be a colourless liquid, slightly saline to the taste. By evaporation, muriate of soda was obtained, and the same salt was indicated also by nitrate of silver. Hence we may conclude it to be analogous in composition to the saliva.

The BILE is one of those fluids, which has attracted peculiarly the notice of chemists, and which is, therefore, better understood than most others. It is to the labours of Fourcroy, and still more recently of Thenard,[*] who has published two excellent memoirs on the bile, that we are chiefly indebted for our knowledge of its composition.

The bile of the ox, from the greater quantity of it which may be procured, has been mostly the subject of experiment. Its colour is commonly yellowish green, and very rarely deep green. When mixed with syrup of violets or infusion of turnsole, it produces no other change than what any other liquid of the same colour would effect. Its taste is bitter and at the same time sweetish, and excessively nauseous. Its smell is peculiar: and something like that of melted fat. Its specific gravity is 1026; its consistence variable, from that of a thin mucilage to that of synovia. Sometimes it is limpid, and, at others, contains flocculi of a yellow matter, which may easily be separated by water.

When submitted to heat, ox-bile first deposites a portion of coagulated matter, and yields a liquid, which has the peculiar smell of bile, and which throws down a white precipitate from acetate of lead. The solid residuum has a yellowish green colour; is very bitter; somewhat deliquescent; and entirely soluble in water and in alcohol. It melts at a moderate heat, and is decomposed by a still stronger one, the products being more oil, and less carbonate of ammonia, than from animal matters in general. A very bulky coal containing several neutral salts remains in the retort. The salts extracted from this coal, taking them in the order of their quantities, are muriate of soda, phosphate of soda,

* *Memoires d' Arcueil*, vol. i.

phosphate of lime, and sulphate of soda. Traces, also, are discovered of oxide of iron.

The uncombined soda in bile does not exceed $\frac{1}{200}$ its weight; and as this very minute quantity of alkali must be quite incapable of dissolving the large proportion of resin, which exists in that fluid, Thenard was induced to turn his attention to the discovery of some other solvent of resin, existing as a component of bile. Super-acetate of lead (the common sugar of lead of commerce) precipitates, he found, not only the resin, but the peculiar substance of which he was in search, in union with oxide of lead. But an acetate with a larger proportion of base (formed from eight parts of sugar of lead and one of litharge) produced a different effect; and precipitated only the albumen and the resin. When the remaining liquid was filtered, and the lead separated by sulphuretted hydrogen gas, it gave, on evaporation, a residue having less bitterness and considerably sweeter. In this state, the solvent of the resin could not be considered as pure, since it retained in solution a quantity of acetate of soda, arising from the decomposition, by the acetate of lead, of the salts of soda existing in the bile. He again, therefore, precipitated the solution by acetate of lead saturated with oxide, and obtained an insoluble compound of the peculiar matter and oxide of lead. This was dissolved in vinegar, the oxide of lead separated by sulphuretted hydrogen, and the acid expelled by evaporation.

This substance, to which Thenard has given the name of *picromel*, possesses the property of rendering the resin of bile easily soluble in water. Three parts are sufficient to one of the resin. The characters of picromel are, that it is insoluble in water and alcohol, and incapable of being crystallized; that it precipitates nitrate of mercury and acetate of lead with excess of oxide; and that it forms, with resin and a minute quantity of soda, a triple compound, which is not decomposable by acids nor by alkaline or earthy salts.

The resin is to be considered as the cause of the smell, and, in great part, of the colour and taste of the bile. It is solid; very bitter; and, when pure, green, but when melted it passes to yellow. It is soluble in alcohol and in pure alkalis, and is precipitable from the former by water, and from the latter by acids.

The yellow matter appears to be peculiar to the bile, and to possess characters distinct from those of other animal substances. Its presence seems to render the bile putrescent; and it is, also, the source of the concretions, which form in the gall-bladder of

oxen. Insoluble by itself, it becomes soluble by the intervention of soda, resin, and picromel; and, whatever be the solvent, it is precipitated by acids.—In the analysis of bile, the first step was to separate this yellow matter, by adding nitric acid, and to free it from the portion of resin which adheres to it. Into the remainder, acetate of lead with excess of oxide (prepared as already directed) was poured, and an insoluble compound was formed, consisting of oxide of lead and resin, from which nitric acid detached the latter in the state of soft green flakes. Sulphuretted hydrogen was then passed through the liquid, which was separated by filtration from the precipitate and evaporated to dryness. Deducting, from its weight, that of the acetate of soda formed by the decomposition of acetate of lead, the weight of picromel was obtained. The saline substances were determined by calcination, lixiviation, and other common processes.

In this way, the composition of ox-bile was determined as follows :

Water	- -	700 *or a little more*
Resin	- -	24
Picromel	- -	60.5
Yellow matter	-	*variable—in this case* 4.
Soda -	- -	4
Phosphate of Soda		2
Muriate of soda	-	3.2
Sulphate of soda	-	0.8
Phosphate of lime	-	1.2
Oxide of iron	-	- *a trace.*

800

The bile of the dog, the sheep, the cat, and the calf was found on analysis to be precisely similar to that of the ox. The bile of the pig, on the contrary, contained neither albumen, yellow matter, nor picromel. It consisted merely of resin in great quantity, of soda, and of salts, the nature of which has not yet been ascertained. It was entirely decomposed by acids, and even by the weakest, the acetic.

The bile of birds contains a large quantity of albuminous matter. The picromel, which is extracted from it, is not sensibly sweet; but on the contrary has a sharp and bitter taste. It contains only an atom or two of soda, and does not precipitate the super-acetate of lead.

HUMAN BILE was, also, an object of Mr. Thenard's researches;

and his experiments, he is of opinion, have led him to as accurate a knowledge of it, as of any other species.—Its colour varies considerably ; sometimes it is green, almost always brownish yellow, and sometimes it is without colour. Its taste is not very bitter. It is seldom perfectly limpid ; for it generally holds suspended in it a certain quantity of yellow matter, which is sometimes even present in such quantity, as to render the bile clotted. When it is filtered, and submitted to a boiling heat, it becomes thick and emits the smell of white of egg. Evaporated to dryness, it affords an extract, which is equal to $\frac{1}{11}$th the weight of the bile. This extract, by calcination, affords precisely the same salts as are found in ox-bile, viz. uncombined soda ; muriate, sulphate, and phosphate of soda ; phosphate of lime ; and oxide of iron.

All the acids decompose human bile, and precipitate from it a large quantity of albumen and of resin. These may be separated from each other by alcohol. By the application of acetate of lead, no picromel can be discovered ; nor is any other ingredient found in human bile than yellow matter, albumen, resin, and saline substances. The proportions, ascertained by Thenard, are the following :

Water - - - - - - -	1000*
Yellow matter, insoluble and floating in the bile, a variable quantity from 2 to - -	10
Yellow matter in solution - - - -	*a trace.*
Albumen - - - - - - -	42
Resin - - - - - - -	41
Soda - - - - - - -	5.6
Phosphates of soda and lime, sulphate and muriate of soda, and oxide of iron - -	4.5
	1100

The yellow matter appears to be, in every respect, similar to that of ox-bile. The resin is yellowish ; very fusible ; very bitter, but less so than that of ox-bile ; soluble in alcohol, from which it is precipitated by water ; and soluble in alkalis, from which it is thrown down by acids. In water it appears scarcely to dissolve ; and yet sulphuric and nitric acids occasion a precipitate from water which has been digested on it.

If bile be submitted to the action of galvanism, Mr. Brande has

* These are the numbers given by Thenard (*Memoires d'Arcueil,* i. 57 ;) but as their sum exceeds 1100, it is probable that the error will best be corrected by reducing the proportion of water.

found that coagulation takes place at the negative pole, where soda also appears. At the positive pole, muriatic and phosphoric acids are evolved.

BILIARY CALCULI. The composition of biliary concretions differs in different animals. Those of the ox contain traces of bile, which is removable by the action of water, after which they are entirely destitute of taste and smell. Their colour is a yellow of so much beauty as to render them a valuable pigment. They undergo no change at a heat below redness: but at this temperature they melt and swell, and after yielding the usual animal products, give about one sixth their weight of a white matter which is phosphate of lime. They are nearly insoluble both in water and in alcohol ; and with some difficulty in alkalis, from which they are precipitated, in green flocculi, by acids. Boiling muriatic acid takes up only a small quantity, and renders them green. Hence they appear to be homogeneous ; and to possess properties identical with those of the yellow matter of the bile of oxen, and of human bile.

The calculi of the human gall-bladder have been more attentively examined than those of the ox. It had been long known that they enter into fusion at a low temperature, and that the alkalis, and the fixed and volatile oils effect their solution. One of their distinctive characters was first pointed out by Poulletier de la Salle, viz. that of being soluble in boiling alcohol, and precipitable, on cooling, in the form of shining scales. Fourcroy afterwards discovered several important facts respecting them, and especially their resemblance to the substance which has been already described under the name of adipocire.

Of the calculi examined by Thenard, only a small number were formed of white plates, crystalline and shining, and entirely adipocirous. Many consisted of yellow laminæ, containing, besides from 88 to 94 *per cent.* of adipocire, six or twelve of a colouring substance. A few were greenish on the outside, and yellow in their interior; several were covered, in spots at least, with a blackish brown crust, containing very little adipocire, but internally were like the rest. In all, excepting the perfectly white, there were traces of bile, discoverable by the action of water.— Calculi from the intestines were found to be similar to those of the gall-bladder.

We may conclude, therefore with Fourcroy, that some of the calculi of the human gall-bladder consist entirely of adipocire ; and that others are composed of the same substance, with the addition

of a quantity of colouring matter, which is either yellowish or dark brown. When of the former colour, it appears not to differ from the yellow matter of the bile; and when of the latter, to be the same substance with an excess of carbon.

SECTION III.

Of Milk.

THE milk is a fluid, which is secreted by all animals of the class *Mammalia* for the nourishment of their young. Though differing considerably in the different species of animals, yet it admits of the following general description.

It is an opake liquid, of a white colour, with sometimes a slight tinge of blue or yellow. Its taste is sweetish and grateful; but varies occasionally, as does its colour also, with the food of the animal. Its specific gravity is variable; that of cow's milk, according to Brisson being about 1020, and that of ewes' milk 1040.

The milk may be resolved, partly by standing, and partly by agents that do not essentially alter the nature of its components into three proximate ingredients, the cream, curd, and whey.

1. The cream rises, as is well known, to the surface of milk after it has stood for some hours. It has many of the properties of an oil; is smooth and unctuous to the touch; and stains cloth in the same manner as other fat substances. By standing for some days, it becomes gradually thicker, and at length forms a soft solid, in which the flavour of cream is no longer perceived, and that of cheese is substituted in its place.

When cream is agitated, as is done by the common process of churning, it separates into two parts, a thick animal oil, well known by the name of butter, and a fluid which possesses exactly the same properties as milk that has been deprived of its cream. This change has been supposed to be owing to the combination of the cream with the oxygen of the atmosphere; but it takes place, though perhaps not equally well, in vessels from which the air is excluded.

Butter has generally a yellow colour and a soft consistence. At the temperature of 96° or 98°, it melts, and when kept in this state for some time, a portion both of whey and curd separate from it; its transparency being thus increased, but its taste at the same time rendered less agreeable. In this state, however, it may be kept longer without becoming rancid; and it is not improbable that it is in part by combination with the whey, that salt contributes to

the preservation of butter. Butter, therefore, may be considered as an animal oil, united with a portion of whey and of curd.

When milk, either deprived or not of its cream, is mixed with certain substances, or even allowed to stand till it becomes sour, it undergoes a change which is called coagulation, consisting in its separation into a solid substance termed curd, and a fluid called whey. This change may be effected by several agents ; by all acids, and by many neutral salts ; by gum, sugar, and certain vegetable juices ; by the gastric fluid ; and especially by the infusion of the inner coat of a calf's stomach, called *rennet*. The precipitation by acids, Scheele has explained, by supposing that they form, with the curd, a combination which requires more water for solution than milk contains ;* and accordingly the curd is found always to contain a portion of that acid by which coagulation has been produced. But, in other cases, the coagulation cannot be thus accounted for; and is, indeed, altogether inexplicable. Thus the infusion of a piece of calf's stomach, not larger than half a crown, coagulates a quantity of milk sufficient for making a cheese of sixty pounds weight ;† although the quantity of coagulating matter cannot in this case exceed a few grains.

The curd of milk, when pressed, salted, and partly dried, composes cheese. In good cheese, however, there is always a large proportion of butter, which is enveloped in the curd, and is not afterwards easily separable. Curd, therefore, for exhibiting its chemical properties, should be prepared from milk, which has been deprived of cream, and should be made by the intervention of rennet. It is a white solid substance, insoluble in water and in alcohol, but readily soluble in pure alkalis, and precipitable therefrom by acids, though in a state more like tallow than the original curd. During solution in alkalis, a strong smell of ammonia is produced ; and hence curd appears to be converted, by their action, into volatile alkali and fat. Liquid ammonia also dissolves curd ; and it appears to be soluble by the pure alkaline earths. From the resemblance of its properties to those of the coagulated white of an egg, Scheele was induced to regard cheese as identical with albumen ; and it is not improbable that if the curd could be obtained perfectly pure, their properties would exactly agree. By the combustion and calcination of curd, it appears, however, to afford a larger proportion of phosphate of lime and other saline substances, than is obtained from the coagulated white of an egg.

* Essays, p. 267.   † Holland's Cheshire Report, p. 263.

The whey, or liquid which remains after the separation of all the curd, is a thin and almost transparent fluid, of a yellowish green colour and a pleasant sweetish taste. It still contains, generally, a portion both of curd and of butter; the former of which may be separated by a boiling heat, in the form of a coagulum. The buttery matter, also, separates by heat, especially if the whey be previously allowed to become sour.* Whey contains, indeed, in its recent state, some uncombined acetic acid.

When whey which has been deprived, as much as possible, of the butter and curd, is slowly evaporated, it yields the substance, already described under the name of sugar of milk. Besides this substance, it contains, also, several saline bodies, viz. muriates of potash and soda, phosphates of lime and of iron, and sulphate of potash; and a peculiar animal matter, which gives a precipitate, with infusion of galls, and affords carbonate of ammonia by distillation. Sour whey has been supposed to contain a peculiar acid called the lactic; but a more accurate examination of its properties has proved this acid to be merely acetic, holding in solution a quantity of animal matter, which disguises its ordinary qualities.

From this account of the composition of milk, several properties of the entire fluid may be understood. When fresh milk is boiled, its albuminous part is not coagulated into a mass like the white of an egg, on account of the large quantity of water, through which it is diffused; but a thin pellicle forms on the surface, which, if removed, is immediately replaced by another; and thus the whole of the albumen may be separated in successive portions. If the pellicle fall to the bottom, it becomes burnt, and gives the milk a peculiar flavour.

In order to procure butter from milk, it is not necessary, in the first place, to separate the cream; for butter may be obtained at once by the churning of milk, and has then the name of milk-butter. It is inferior, however, to butter made from cream in consequence of containing a larger proportion both of whey and of curd.

Milk is susceptible of the vinous fermentation, and is employed, by the Tartars, in making a sort of wine, which they call *Koumiss*. It is prepared chiefly from mares' milk, and has an agreeable sweetish taste. By distillation, it yields a considerable quantity of alcohol. What is most remarkable with respect to this fermented liquor, is that it does not appear to owe its origin to the saccharine part of the fluid; for Fourcroy and Vauquelin have found

* Cheshire Report, page 262.

that milk, after fermentation, yields as much sugar of milk as before.

There appears to be a considerable difference in the quality of the milk of different animals. Human milk is sweeter than that of cows; and yields a larger proportion of cream; but from this the butter cannot be separated by agitation. It deposites, also, a part of its curd by mere repose. Asses' milk bears a stronger resemblance to human milk than to any other. The cream is but in small quantity, and yields a soft white and nearly tasteless butter. The curd is so abundant, as even to separate on standing, before the milk becomes sour. Goats' milk yields a remarkably thick and unctuous cream, and abounds also in curd. The milk of sheep bears a strong resemblance to that of cows, and yields a large proportion of curd of a fat and unctuous kind. Mares' milk is thin, insipid, and affords very little cream, from which it is very difficult to separate any butter by agitation.

SECTION IV.

Of the Mucus of the Nose; the Tears; the Humours of the Eye; and the Liquor of Surfaces and of Cavities.

1. *The mucus of the nose* was examined by Fourcroy and Vauquelin, in the state in which it is discharged during catarrh. Its principal qualities appear to be owing to the large proportion, which it contains, of the substance termed by Dr. Bostock animal mucus. By exposure to the air, this substance becomes viscid; but, when recently secreted, its consistence does not appear to be thicker than that of tears. It contains besides other neutral salts, a small proportion of carbonate of soda; and hence it precipitates the solutions of barytes and of lime. Water does not dissolve it, and it can only be brought into a state of diffusion by agitation. The acids thicken it, when used in small quantity; but in a larger proportion they dissolve it. Pure liquid alkalis decompose it, and extricate ammonia. Oxy-muriatic acid renders it thick and dry; and reduces it to a state almost resembling parchment.

2. The *tears* appear to differ from the mucus of the nose in no respect, except in being of a more fluid consistence. They are perfectly pellucid, have a saline taste, and a specific gravity rather greater than that of water. They change the colour of syrup of violets to green, owing to their containing a portion of uncombined soda. Mr. Hunter found that when tears are exposed to a temperature of 160°, a coagulum is formed; and that a substance still remains in solution, which is coagulable by Goulard's extract

of lead.　These properties indicate the presence both of albumen and of mucus.　By evaporation the tears afford a yellow extract which is insoluble in water, but is readily soluble in alkalis.　Sulphuric acid disengages from this extract both carbonic acid and muriatic acid gases.　After its combustion, phosphate of soda and phosphate of lime are also discovered in it.　Fresh tears are decomposed by oxy-muriatic acid, and a precipitate is thrown down in flakes, which resembles the matter obtained by evaporation. Tears, therefore, are composed of water ; an animal fluid resembling albumen ; another fluid which is probably mucus ; and various neutral salts.

3. *The humours of the eye.*　The aqueous humour is a clear transparent liquid, of the specific gravity 1009.　It has little smell or taste, and scarcely affects blue vegetable colours.　By evaporation it leaves a residuum, amounting to about 8 *per cent.*　Boiling occasions a slight coagulation ; and tan precipitates it, both before and after being heated.　Nitrate of silver precipitates muriate of silver from it, but no other metallic salts affect it.　Hence it may be inferred, that the aqueous humour consists of a large proportion of water ; and of albumen, gelatine, and several neutral salts.

The vitreous humour agrees with the aqueous as to the nature of its ingredients, and differs only in their proportion.　In the crystalline lens, both albumen and gelatine are present in considerably larger quantity.　It is soluble in cold water ; but the solution is coagulated by heat, and by the addition of tan.　Its specific gravity is nearly 1100.—It appears, therefore, that all the humours of the eye are composed of the same ingredients, and differ only in the proportion which they bear to each other.

4. *Liquor of surfaces.*　On the surface of every cavity throughout the body a fluid is constantly poured out, in sufficient quantity to lubricate the parts ; and occasionally, also, to keep certain cavities in a state of distension.　To this head may be referred the fluid which moistens the pleura and the peritonæum, and the contents of the pericardium, of the ventricles of the brain, and of the amnios.　It is only a part of these, however, that have been accurately examined.

The liquor of the pericardium has been analyzed by Dr. Bostock. It had the appearance of the serum of the blood ; and when exposed to the heat of boiling water, became opake and gelatinous. By slow evaporation it left a residuum equal to $\frac{1}{13}$ of the whole. It was precipitated by oxy-muriate of mercury ; after the action

of which infusion of galls had no effect, but a copious sediment
was produced by Goulard's extract. From these characters Dr.
Bostock is disposed to consider it as a compound of albumen and
mucus with muriate of soda and water, but without any gelatine.
The following proportions he assigns as approximations :

Water - - - -	92
Albumen - - - -	5.5
Mucus - - - -	2
Muriate of soda - -	0.5
	100*

The liquor of the amnios, or the fluid which surrounds the fœ-
tus, is remarkable, in the cow, for affording a peculiar acid, al-
ready described under the name of amniotic. In the human sub-
ject, the composition of this fluid is entirely different ; none of
the amniotic acid appearing to exist in it. The only ingredients,
that are found in it, are albumen, gelatine, with a portion of mu-
riate and carbonate of soda and some phosphate of lime. It is
precipitated by heat, by acids, by alcohol, and by infusion of galls.

The *synovia*, or the fluid which is found in the cavities of the
joints, may, from its office in lubricating the parts in which it is
found, be described in this place, though in composition it differs
considerably from the liquor of surfaces. It is at first a viscid li-
quid, but soon becomes gelatinous ; and, after remaining some
time in this state, again assumes a fluid form and deposites a fi-
brous matter. Alcohol separates from it a portion of albumen,
but the remaining liquid remains viscid. Acetic acid destroys its
viscidity, and precipitates a quantity of white threads, which have
a striking resemblance to vegetable gluten. The same substance
is precipitated by the mineral acids, but not unless they are dilut-
ed with a large quantity of water ; for in their concentrated form,
they have the power of dissolving it. By continuing the analysis,
several neutral salts may be obtained, and the proportions of the
entire fluid have thus been stated by Margueron :[†]

Fibrous matter - -	11.86
Albumen - - -	4.52
Muriate of soda - -	1.75
Soda - - - -	0.71
Phosphate of lime - -	0.70
Water - - - -	80.46
	100

* Nicholson's Journal, xiv. 147.   † Annales de Chimie, xiv.

SECTION V.

Of the Urine and Urinary Calculi.

THE urine, though one of the most complicated fluids of the animal body, containing at least a dozen different substances, is perhaps one of those, the composition of which is now best understood. For a long period of time, the attention of chemists seems to have been limited to the extraction of phosphorus and neutral salts from urine ; but a new direction was given to their labours, by the valuable discoveries of Fourcroy and Vauquelin, which were communicated to the National Institute in the year 7.[*] The analysis of the urine has been prosecuted, also, with great success, in this country by Cruickshank,[†] and in Spain by Proust ;[‡] and though some important facts have been contributed by other persons, yet it is chiefly to these four writers, that we are indebted for the materials of its chemical history.

The external properties of the urine need no description ; and indeed none would apply universally to a fluid, which is constantly varying, not only in the diseased but in the healthy state of the body. The following account of its chemical properties is to be understood as applying to the urine which is voided early in the morning, or at least several hours after a meal. In this state it has a deep yellow colour, and an intensely bitter taste. Its specific gravity is variable. Dr. Bryan Robinson fixes it at 1030, water being 1000 ; and Mr. Cruickshank found it to vary from 1005 to 1033. From my own experiments, I am disposed to consider the number stated by Dr. Robinson as a fair general average.

The substances, which appear to me to have been satisfactorily proved to exist in healthy urine, are the following :

1. Water
2. Free phosphoric acid
3. Phosphate of lime
4. Phosphate of magnesia
5. Fluoric acid
6. Uric acid
7. Benzoic acid
8. Urea
9. Gelatine
10. Albumen
11. Muriate of soda
12. Phosphate of soda
13. Phosphate of ammonia
14. Sulphur

The presence of an uncombined acid in urine is shown by its invariably, when recently voided, reddening blue vegetable col-

* Annales de Chimie, xxxi. 48.   † Phil. Mag. ii. 240.
‡ Annales de Chimie, xxxvi. 258.

ours. This effect is owing partly to the phosphoric, and partly to the uric acid which urine contains. The phosphoric acid is the solvent, by which the phosphate of lime is retained in solution ; and, if this portion of acid be saturated, the earthy salt is precipitated. Hence a few drops of pure ammonia, added to recent urine, occasion a white cloud, and a sediment of neutral phosphate of lime afterwards falls, in the proportion of about two grains from four ounces of urine. If lime-water be mixed with urine, a still larger quantity of phosphate of lime is deposited ; for the newly added earth unites with the free phosphoric acid, and a quantity of phosphate of lime is generated in addition to that which before existed in solution. In the precipitate, formed by either of these processes, a small proportion of magnesia is discoverable, which existed, no doubt, in combination with phosphoric acid. The sediment contains, also, according to the recent discovery of Berzelius,* fluate of lime. The presence of the last mentioned substance was ascertained by adding sulphuric acid, which set at liberty vapours of fluoric acid, in sufficient quantity to corrode glass.

When the urine has stood for about 24 hours at a mean temperature, the uric acid and phosphate of lime are in a great measure deposited ; and still more speedily and completely, if the urine be first evaporated to half its bulk. They may be separated from each other, either by diluted nitric acid, which leaves the uric acid, and takes up only the phosphate of lime ; or by calcining the mixture in a red-heat, which destroys the uric acid, but not the calcareous phosphate. By this operation, the uric acid is found to vary considerably ; but the phosphate of lime is pretty constantly in the proportion of a grain from two ounces of urine. The quantity of uric acid, obtained from urine, is greatly increased by adding to that fluid almost any other acid, and allowing it to stand for some days ; at the end of which time small crystalline grains will be found lining the inner surface of the vessel.†

When urine, which has deposited its phosphate of lime and uric acid, is submitted to distillation, a liquid condenses in the receiver, which has a very peculiar and nauseous smell, and effervesces strongly with acids, in consequence of its containing carbonate of ammonia. In the retort there remains a residuum, which, if evaporated to the consistence of honey, composes from $\frac{1}{24}$ to $\frac{1}{36}$ the weight of the urine. When a little of this extract is added to a quantity of nitric acid, diluted with an equal weight of

* Annales de Chimie, lxi. 256.　　† Egan, Phil. Mag. xxiii. 298.

water, a number of shining white or yellowish scales are deposit-
ed, resembling the boracic acid, and in the proportion of $\frac{5}{8}$ or $\frac{7}{8}$
the weight of the extract. This precipitate is occasioned by the
action of the nitric acid on the urea, which is contained in urine;
and to the decomposition of the same substance is owing the car-
bonate of ammonia, obtained from urine by distillation (see the
section on Urea.)

From the extract of urine, the peculiar substance, called urea,
may be separated, by digesting the extract repeatedly with alco-
hol, and decanting the solutions, which are to be gently evapo-
rated. Its proportion varies very considerably; but it has been
stated, by Mr. Cruickshank, at about $\frac{1}{70}$ the weight of the urine,
or one half the inspissated extract. The undissolved residue con-
tains a number of neutral salts, consisting of muriate of potash,
muriate of soda, phosphate of soda, and phosphate of ammonia.
Muriate of ammonia is, also, occasionally found, and is dissolved,
along with the urea, by the alcohol. These salts admit of being
separated from each other by solution and evaporation. The mu-
riates, at a certain degree of concentration, form a pellicle, which
is to be removed while the liquor is hot. The solution, when
cold, deposites two sets of crystals; rhomboidal prisms, which
are the phosphate of ammonia; and rectangular tables, consisting
of phosphate of soda.

Along with the urea, a portion of benzoic acid is, also, taken
up by the alcohol. The presence of this acid in urine may be
shown, by evaporating it to the consistence of syrup, and pouring
in muriatic acid; when a precipitate appears, which consists of
benzoic acid. In human urine its proportion is small; but in
that of herbivorous quadrupeds, so large a quantity exists as to be
worth extraction. On the average, Vauquelin has shown that it
forms about $\frac{1}{300}$ of the urine of this class of animals.[*]

Albumen and gelatine exist, also, in the urine, but in very va-
riable proportion. When urine is heated nearly to the boiling
temperature, a white flocculent precipitate often forms in it.
This is in part phosphate of lime, thrown down by the ammonia
resulting from the decomposition of urea; but it also contains
coagulated albumen, which remains after adding muriatic acid to
dissolve the calcareous phosphate. In dropsy, the proportion of
albumen is often sufficient to produce a distinct coagulation both
by heat and acids. Gelatine is discovered, on adding infusion of

* *Annales de Chimie,* lxix. 311.

galls, by a precipitate which amounts, according to Mr. Cruick-shank, to $\frac{1}{240}$ part the weight of the urine.

Sulphur was discovered in urine by Proust. This fluid, he observes, blackens silver vessels in which it is evaporated, and scales are detached which consist of sulphuret of silver. Sulphuretted hydrogen gas, he finds also, is disengaged from urine which has been kept about fifteen days.

The same distinguished chemist supposed that he had discovered carbonic acid in urine, by examining the air bubbles which arise from this fluid during ebullition. There can be little doubt, however, that the carbonic acid, thus detected, arises from the decomposition of urea by the increased temperature. To the same source, also, (urea) may be referred the carbonate of lime, found by Proust on the surface of casks in which urine had been kept. By the decomposition of urea, carbonate of ammonia is formed; and this, re-acting on the phosphate of lime contained in urine, would doubtless compose carbonate of lime. The occasional presence of the sulphate of soda rests on better evidence; for it frequently happens that only a part of the precipitate, formed by adding muriate of barytes to urine, is dissolved by muriatic acid; thus indicating the formation of sulphate of barytes.

The acetic acid and resinous matter, which Proust imagined he had discovered in urine, may be accounted for by supposing, that they were produced, rather than separated, by the processes which he employed. At least their existence in healthy urine is not a little equivocal. The acetic acid he obtained by distilling a fresh extract of urine with sulphuric acid; and the resinous matter by diluting the residue of this distillation when beginning to grow thick, with a large quantity of cold water; the excess of acid being afterwards removed by a little alkali. The resin thus produced he found to bear a striking resemblance to castor.

The putrefaction of urine is attended with a series of changes, somewhat analogous to those accompanying its distillation. The urea, which it contains, is decomposed and converted into carbonate of ammonia, which neutralizes all the redundant acids, and precipitates phosphate of lime. At the same time, the ammonia, uniting with the phosphate of magnesia, composes a salt, which settles in white crystals on the inner surface of the vessel. This salt is the ammoniaco-magnesian phosphate, which constitutes so large a part of some urinary calculi. The albumen and gelatine contained in the urine also undergo decomposition, and flakes are deposited, which consist of both these substances. Acetic acid is

generated, and becomes saturated with ammonia. Acetate and carbonate of ammonia, and the ammoniaco-magnesian phosphate appear, therefore, to be the principal substances generated by the putrefaction of urine.

Some important facts have been ascertained by Mr. Cruickshank, respecting the changes that the urine undergoes in different diseases. In dropsy, the urine was coagulated so completely by heat and by acids, as to differ but little from the serum of the blood. When this disease, however, arose from a morbid state of the liver, the urine was not coagulable ; but was observed to be small in quantity, high coloured, and to deposite a considerable portion of pink sediment (probably the *substance rosacee* of Proust.) In inflammatory affections, the urine was found to be loaded with albumen. In gout, towards the end of the paroxysm, the urine deposited a lateritious sediment, which consisted of a very minute quantity of uric acid, a larger quantity of phosphate of lime, and some peculiar animal fluid not soluble in water. The urine of jaundiced persons contained a small quantity of bile, which was discoverable by the addition of muriatic acid. Hysterical urine was remarkable for a large proportion of saline ingredients, but had scarcely any animalized matter.

The composition of the urine differs essentially in the different classes of animals. Urea appears to be a constituent of the urine of all animals, so far as it has hitherto been examined; but the uric acid is not found in herbivorous quadrupeds, the urine of which contains, instead of it, a large proportion of benzoic acid. That of the horse and of the rabbit are remarkable for becoming milky after being voided, in consequence of the deposition of carbonate of lime. The urine of the rabbit contains, also, carbonates of magnesia and potash, and sulphates of potash and lime. The urine of the cow, besides a larger proportion of benzoic acid, holds in solution carbonate and sulphate of potash and muriate of potash.—The urine of domestic fowls, which is voided through the same passage as the excrement, was found by Fourcroy and Vauquelin, and more lately by Chevreul, to contain uric acid.

URINARY CALCULI. Connected with the analysis of urine is that of the concretions, which are found in the bladder, and which occasion a disease, equally formidable from its symptoms and its remedy. Little was known respecting their chemical composition, till the time of Scheele ; to whom we owe on this, as on many other subjects, the first and therefore the most difficult steps towards accurate analysis. By the discovery of the uric acid in

one of the most common varieties of calculus, and in the ordinary
urine, he paved the way to every thing that has been since ascertained, respecting other varieties; and his experiments have been
most ably followed up by those of Dr. Wollaston, and of Fourcroy
and Vauquelin. It is only justice to Dr. Wollaston, however, to
state that the principal distinctions of the several species of calculus were pointed out by him in the year 1797,* in a memoir, not
less distinguished by the importance of its facts, than by the simplicity with which they are narrated. Two years afterwards the
experiments of Fourcroy and his associate were communicated to
the National Institute; so that the title to priority unquestionably
belongs to our own countryman.

The ingredients of urinary calculi are much less numerous
than those of the urine. The following appear to be the only
substances, the existence of which, in concretions of this sort, is
sufficiently established; *viz.* uric acid; phosphate of lime; ammoniaco-magnesian phosphate; oxalate of lime; silex; and an
animal matter, which serves the purpose of a cement to the earthy
ingredients. To these, Proust has added the carbonate of lime;†
but, in this instance, there is reason to doubt of an authority which
is in most cases unquestionable. It is scarcely ever that any of
these substances is found singly. Nevertheless, the predominance of some one of them gives to the concretion its peculiar
characters; and determines the genus to which it should be assigned. Several arrangements of urinary calculi have been contrived. Fourcroy and Vauquelin have enumerated three genera,
which they have divided again into no less than twelve species.
In these subdivisions, however, several minute differences have
been attended to, which are scarcely sufficient grounds for specific distinctions; and it appears to me sufficient for every purpose
of arrangement to class them under the four following heads:

I. Calculi which are chiefly composed of uric acid:

II. Calculi principally composed of the ammoniaco-magnesian
phosphate:

III. Calculi consisting, for the most part, of phosphate of lime;
and

IV. Calculi which derive their characteristic property from
oxalate of lime.

I. The calculi composed entirely of uric acid are of very rare
occurrence; but those, in which it prevails, and gives the charac-

* See the Philosophical Transactions for that year.
† Annales de Chimie, xxxvi.

ter of the species, form a very considerable proportion. Calculi of this kind are of various sizes, from that of a bean to that of a large egg. Their shape is most commonly a flattened oval; but when more than one are found, they acquire, by friction against each other, several sides and angles. The best view of their internal structure is obtained by sawing them through their longest and widest diameter, when they exhibit generally a central nucleus, of more compact texture, and greater hardness and lustre, than the rest of the stone; but generally of the same figure. From this to the circumference, a number of distinct layers are perceived; and these layers, when the calculus is broken, exhibit a radiated structure, the radii converging towards the centre. The harder varieties, when divided by the saw, admit of some degree of polish, and bear a considerable resemblance to wood. Their colour is various, but generally of different shades of yellow, from pale straw yellow to a deep shade of that colour, approaching brown, or sometimes brown with a mixture of red. Their specific gravity, according to Fourcroy, varies from 1.276 to 1.786; but generally exceeds 1.500.

The chemical characters of calculi of this kind resemble those of the uric acid. When burned in a crucible, they emit the smell of horn, and are almost entirely consumed; a black dense coal remaining which amounts to about $\frac{1}{8}$ the weight of the calculus. They dissolve, either wholly or in great measure, in solutions of pure potash and pure soda, and are precipitated again by acids. A very striking property of this sort of concretions is, that when a few grains are heated with a small quantity of nitric acid, and the mixture evaporated to dryness, a beautiful red substance remains, which dissolves in water and tinges the skin of the same colour.

II. The ammoniaco-magnesian phosphate is scarcely ever found without an admixture of some other substance, especially of a small proportion of phosphate of lime. Calculi of this sort are easily discriminated, from those of the first species, by their colour, which is white, and generally pure white. They attain a much greater size than uric acid calculi; and, in one or two instances, have increased so as to fill the whole capacity of the bladder. The layers are distinguishable only by different degrees of hardness and density; and small cells are often formed by the interrupted deposition of these layers, which are lined with sparkling crystals. The calculi of this kind are soft, and their powder

dissolves sufficiently in the mouth, to give a distinct sweetish taste.

Boiling water acts upon the ammoniaco-magnesian phosphate; and the calculus loses about $\frac{4}{10}$ of its weight, which is deposited, on cooling, in the form of shining crystals. When exposed to heat they first become black, emit a smell of ammonia, and a white powder is left, which fuses when the heat is more strongly urged. From this property, Dr. Wollaston gave them the name of *fusible calculi*. Most acids (even sulphuric acid of the specific gravity 1020) dissolve them rapidly, and deposite them again on the addition of alkalis. Pure alkalis do not dissolve them, butdisengage ammo-nia. To extract the phosphoric acid, Dr. Wollaston dissolved the calculus in nitric acid, and added nitrate of mercury. Phosphate of mercury was thus precipitated, from which the base was ex-pelled by heat, and the acid remained pure. By adding sulphu-ric acid to the decanted liquor, and evaporating to dryness, sul-phate of magnesia remained, which was obtained in crystals by so-lution and evaporation.

III. The third species of calculus, composed chiefly of phos-phate of lime, is usually, on its outer surface, of a pale brown col-our, and so smooth as to appear polished. When sawed, it is found to be regularly laminated, and the layers adhere so slightly, as to be readily separated into concentric coats. Internally the colour is white, but not of that pure and brilliant kind, which distinguishes the ammoniaco-magnesian phosphate. The small crystals, also, which occur in the former variety, are never found in this ; and its powder, when rubbed between the fingers, is con-siderably more harsh and rough.

The phosphate of lime calculus dissolves, though slowly, in di-luted nitric, muriatic, and acetic acids (but not in sulphuric acid of the specific gravity 1020,) and is precipitated unchanged by al-kalis. A small fragment put into a drop of muriatic acid, on a piece of glass over a candle, is soon dissolved ; and, when the acid is evaporated, crystallizes in needles, which make angles of 60° and 120° with each other. This property Dr. Wollaston consid-ers as a very delicate test of the phosphate of lime.

IV. Calculi of the fourth kind, though their composition was not ascertained, have been long distinguished from others, by the peculiarities of their external characters, under the name of *mul-berry calculi*. This epithet has been derived from their resem-blance to the fruit of the mulberry. They are of a much darker colour than the other varieties, and are covered, generally, with

a number of projecting tubercles. Their hardness greatly exceeds that of the other kinds; for it is not easy to reduce them to powder by scraping with a knife. They have also a greater degree of specific gravity, varying, according to Fourcroy, from 1428 to 1976.

Calculi of this species are soluble in muriatic and nitric acids; but not unless the acids are concentrated and heated. The solution by muriatic acid has a deep brown colour, but deposites white crystals on cooling. Pure alkalis do not decompose this variety of calculus; but when it is digested with alkaline carbonates, the oxalic acid is separated, and replaced by carbonic acid. To exhibit the oxalic acid in a separate state, the oxalate of potash may be decomposed by acetate of barytes or super-acetate of lead, and the oxalate of lead or barytes by sulphuric acid. This is the process of Fourcroy; but Dr. Wollaston disengaged the oxalic acid by the direct addition of sulphuric acid to the pulverized calculus, and the crystallization of the acid which was thus detached.

The presence of lime, in this variety of calculus, is demonstrated, in a very simple manner, by burning it in a crucible, and strongly calcining the residuum. By the addition of water, we obtain lime-water. Silex is a very rare ingredient, and has been discovered in calculi, in one or two instances only.

Such are the principal kinds of urinary concretions. If any addition were made to the four classes, under which they have been arranged, I would propose to add two others; the fifth comprehending those calculi, which contain several of the foregoing ingredients, in such a state of admixture as not to be distinguishable without chemical analysis; and the sixth those, in which the different substances are disposed in layers or in concentric strata. It may be proper, however, to give an outline of the classification, proposed by Fourcroy and Vauquelin, after the analysis of more than 600 of these concretions.

GENUS I.—CALCULI COMPOSED OF ONE INGREDIENT ONLY.
Species 1. Calculus of uric acid.
    2. —————- urate of ammonia.*
    3. —————- oxalate of lime.

GENUS II.—CALCULI COMPOSED OF TWO INGREDIENTS.
Species 1. Calculus of uric acid and earthy phosphates in distinct
        layers.

* The existence of urate of ammonia, as an ingredient of calculi, has lately been rendered very questionable, to say the least, by Mr. Brande, with whose experience on this point mine entirely agrees.

2. ———— of uric acid and earthy phosphates intimately mixed.

3. ———— of urate of ammonia and the phosphates in layers.

4. ———— of the same ingredients intimately mixed.

5. ———— of earthy phosphates mixed or else in fine layers.

6. ———— of oxalate of lime and uric acid in distinct layers.

7. ———— of oxalate of lime and earthy phosphates in layers.

GENUS III.—CALCULI COMPOSED OF THREE OR FOUR INGRE-
DIENTS.

Species 1. Calculus of uric acid or urate of ammonia, earthy phosphates, and oxalate of lime.

2. ———— of uric acid, urate of ammonia, earthy phosphates, and silex.

The urinary concretions, which have been extracted from the bladders of inferior animals, differ from those of the human subject in containing no uric acid, and in consisting chiefly of carbonate and phosphate of lime, cemented by animal matter.

SECTION VI.

Of Bones, Shells, Crusts, and Horn.

THE bones of animals are composed partly of earthy salts, which give them solidity and hardness, and partly of animal matter, which serves the purpose of a cement, and keeps the earthy ingredients in a state of union. By long continued boiling, a large part of the animal matter is extracted, and a solution is obtained, which concretes, on cooling, into a gelatinous mass. Hence bones contain gelatine as one of their ingredients. But besides this animalized substance, another is discovered by the slow action of diluted nitric or muriatic acid. Either of these acids dissolves both the earthy salts and gelatine ; and a soft flexible substance remains, retaining in a great measure, the shape of the original bone. This soft and spongy substance seems to be analogous to cartilage ; and is essential to the constitution of all organized bones and shells. Its production appears to be the first step in the formation of bone, and of the other hard coverings of animals. In chemical composition, it has been found by Mr. Hatchett (to whom we owe its discovery) most to resemble coagulated albumen.

Besides the marrow, which is lodged in the hollow cavities of bones, they contain, in the most hard and solid part of their substance, a proportion of oil. This oil makes its appearance in a hard and suetty form, on the surface of the gelatinous mass extracted by boiling. It exudes, also, from the bones of recent anatomical preparations ; and a portion of it passes over, in a separate but altered state, when bones are submitted to distillation. By this process, bones are deprived not only of their oily part, but the other animal substances which they contain are decomposed ; a quantity of carbonate of ammonia is generated ; and in the retort there remain the earthy ingredients blackened by charcoal. By a farther combustion in the open air, this charcoal is destroyed ; and the earthy ingredients are left in a perfectly white state. In this way large quantities of bones are distilled for the sake of the carbonate of ammonia, which is afterwards applied in making the muriate of that alkali. The animal oil (formerly used in medicine, under the name of *Dippel's oil*) is now, on account of its offensive smell, which unfits it for most other purposes, chiefly converted into lamp-black.

When diluted muriatic or nitric acid is poured upon the white ashes of bones, an effervescence takes place, and nearly the whole is dissolved. Solution of pure ammonia added to the filtered liquid, precipitates a white earth in great abundance ; but after it has ceased to produce any effect, the addition of carbonate of ammonia occasions a fresh precipitation. What is thrown down by the pure alkali is composed of phosphate of lime and a small quantity of phosphate of magnesia ; and the precipitate by the mild alkali is the carbonate of lime. The proportions, deduced from the analysis of ox-bones by Fourcroy and Vauquelin, are the following :

Animal matter - - -	51
Phosphate of lime - -	37.7
Carbonate of lime - -	10
Phosphate of magnesia	1.3
	————
	100

Besides the above ingredients, Mr. Hatchett discovered in bones a minute quantity of sulphate of lime ; and Berzelius has detected a combination of fluoric acid with the same earth, which Morocchini had previously found in enamel. Berzelius has given the following tabular view of the results of his analysis.[*]

* Annales de Chimie, lxi. 257.

	Dry Human Bones.	Enamel of Human Teeth.	Dry Ox Bones.	Enamel of Ox Teeth.
Cartilage - - -	32.17		33.30	3.56
Blood vessels - -	1.13			
Fluate of lime - -	2.0	3.2	2.90	4.0
Phosphate of lime - -	51.04	85.3	55.45	81.0
Carbonate of lime - -	11.30	8.0	3.85	7.10
Phosphate of magnesia -	1.16	1.5	2.05	3.0
Soda, muriate of soda, water, &c. - -	1.20	2.0	2.45	1.34
	100	100	100	100

Human teeth are composed of the same ingredients as the enamel, and in the same proportion, except that, in addition to other ingredients, they contain cartilage. This cartilaginous basis Mr. Hatchett found to remain, in the original shape of the tooth, after removing the other component parts by diluted nitric acid. The enamel on the contrary, dissolves entirely in diluted nitric acid, and is, therefore, free from cartilage. But it probably contains gelatine, and to the solution of this animal substance (which is not afterwards precipitable by alkalis) may perhaps be ascribed the loss, which forms part of the following results of the analysis of enamel obtained by Mr. Pepys. He found the enamel of human teeth to consist of

Phosphate of lime	- -	78
Carbonate of lime	- -	6
Loss and water	- -	16
		100

The substance of the teeth Mr. Pepys found to be composed as follows :

	Roots of the Teeth.	Teeth of Adults.	First Teeth of Children.
Phosphate of lime - - -	58	64	62
Carbonate of lime - - -	4	6	6
Cartilage - - - -	28	20	20
Loss - - - - -	10	10	12
	100	100	100

The shells, with which several marine and also some land animals are covered, have been divided by Mr. Hatchett into two classes. The first, from their resemblance to porcelain, he has termed porcellaneous shells. To this class belong the several

species of *voluta, cypæra,* &c. The second class approach in their characters to mother of pearl. The shell of the fresh water muscle, and of the oyster may be arrranged under this head; and pearl itself has the same characters and chemical composition. Comparing the experiments on both classes, Mr. Hatchett concludes that porcellaneous shells consist of carbonate of lime, cemented by a very small portion of animal matter; and that mother of pearl and pearl do not differ from these, except in containing a smaller proportion of carbonate of lime. This, instead of being merely cemented by animal matter, is intermixed with and serves to harden a membranous or cartilaginous substance, which is capable of retaining its form, after the removal of the earthy ingredient.

The covering of crustaceous animals (as echini, star fish, lobsters, crabs, &c.) differs in composition from marine shells, and approaches that of the eggs of birds. These, Mr. Hatchett found, are composed of carbonate of lime with a small proportion of phosphate, cemented by animal matter.

Horn differs essentially from all the substances, that have been described in this section. The proportion of earthy matter obtained by its combustion, scarcely amounts to $\frac{1}{300}$ part. It appears to consist principally of gelatine and coagulated albumen.

SECTION VII.

Of Muscle, Membrane, Tendon, Ligament.

THE *muscular flesh* of animals consists chiefly of the peculiar substance, which has been already described under the name of *Fibrin.* Though generally of a redish colour; yet, essentially, muscular fibre is white, and may be obtained in this state, if all the soluble parts be first washed away by long continued affusions of water, which acquires a dark colour. The solution, if concentrated by boiling, gelatinates on cooling; and hence gelatine appears to be one of the constituents of muscle. Albumen is another ingredient, and makes its appearance by a deposition of coagulated flocculi in the heated watery solution. A portion of fat, also, frequently concretes on cooling; but this is to be considered rather as an accidental admixture. From the gelatine, when evaporated to dryness, alcohol removes a peculiar kind of extract, first described by Thouvenel. The entire muscle, when calcined, leaves about 5 *per cent.* its weight of saline matter, composed chiefly of

phosphates of soda, ammonia and lime, and carbonate of lime. Muscular flesh, therefore, is composed of

1. Fibrin	4. Albumen
2. Gelatine	5. Neutral salts
3. Extract	

By the action of boiling water on muscle, the gelatine is dissolved, along with the extract and colouring matter, and this solution composes the basis of soups. The albumen and fibrin remain in a coagulated form.—In the roasting of meat, the watery juices partly exude, and carry out with them a portion of gelatine and extract, a strong solution of which in water constitutes the *gravy* of meat.

Considerable differences exist in the colour and other properties of the muscular flesh of different animals; but the cause of these differences is not well understood. It depends, most probably, on the proportion which the fibrin, albumen, and other principles bear to each other. Gelatine appears to be most abundant in the flesh of young animals; and albumen and extract in that of old ones.

The *tendons*, or *sinews* as they are commonly called, are the strong cords in which muscles terminate, and which connect them with the bones. They differ from muscle in the total absence of fibrin; and in being completely soluble in water by sufficiently long boiling. The solution has the properties of gelatine.

The *ligaments* are excessively strong bands, which tie the bones together at the different joints. They are in a great measure, but not completely, soluble by boiling water; and contain, therefore, besides gelatine, some other animal substance, probably coagulated albumen.

Membranes are thin semi-transparent substances, which sometimes form bags for containing fluids, and sometimes line the different cavities of the body. They are for the most part, though not entirely, soluble in water; and are composed, therefore, chiefly of gelatine. Hence by the common process of tanning, membranes are convertible into leather.

SECTION VIII.

Of the soft Coverings of Animals, viz. Nails, Scales, Skin, Hair, Feathers, and Wool.

THE *nails* and *hoofs* of animals most nearly resemble horn in chemical composition. Their basis seems to be a series of mem-

branes composed of coagulated albumen, in which is deposited a
quantity of gelatine. Long boiling does not entirely dissolve
them. By calcination they have only a very small proportion of
earthy matter.

The *scales* of serpents also resemble horn in their chemical
composition and properties. The scales of fish, on the contrary,
are more nearly analogous to mother of pearl, and are composed
of alternate layers of membrane and phosphate of lime.

The *skin* consists of two distinct parts, a tough white membrane
on the outside which is almost insensible, and an internal one, full
of blood vessels and nerves, and distinguished by great sensibility.
Between these two, in the human body, is a soft mucous substance
called *rete mucosum.*

1. The external layer, called the *cuticle* or *epidermis,* is best
separated from the parts beneath by the action of a blister. It is
not soluble in water, nor in acids, unless they are sufficiently con-
centrated to decompose it. Hence it differs from gelatine. Al-
kalis however dissolve it ; and, in this respect, it agrees with co-
agulated albumen, which it resembles, also, in receiving a yellow
tinge from nitric acid.

2. The *cutis vera,* which lies beneath the cuticle, consists of a
number of fibres crossing each other in various directions, and has
considerable firmness and elasticity. Long continued boiling in
water entirely dissolves it, and a solution is obtained which gelat-
inates on cooling, or by farther evaporation, may be wholly con-
verted into glue.

The true skin is composed, therefore, almost entirely of gela-
tine ; but under some modification which renders it insoluble in
water. It is this substance that adapts the skins of animals for
two important uses, that of being converted into leather by the re-
ception of the tanning principle, and that of furnishing glue.

3. Of the *rete mucosum* very little is known. It is that part of
the skin, on which its colour depends ; and by the sufficiently long
continued application of oxy-muriatic acid, it has been found that
in the negro it may be entirely deprived of its colour.

Hair has been examined with considerable attention by Vauque-
lin. He effected a complete solution of it in water by using a Pa-
pin's digestor. The application of the proper temperature re-
quired, however, some caution ; for if raised too high, the hair
was decomposed and gave carbonate of ammonia, empyreumatic
oil, and sulphuretted hydrogen. The solution always contained a
sort of bituminous oil, the colour of which approached to that of

the hair which had been dissolved. After separating this oil, the solution was precipitated by infusion of galls and by oxy-muriatic acid ; but did not gelatinate on cooling. Acids occasioned a precipitate, which was re-dissolved by adding more acid. Silver was precipitated from its solutions of a black colour, and lead of a brown.

A diluted solution of potash dissolved hair, excepting a little oil, sulphur, and iron ; and the compound was a sort of soap. The oil, if red hair was employed, had a yellow tinge. Alcohol, also, extracted from hair a portion of oil, the colour of which varied with that of the hair.

The coal, obtained by incinerating hair, afforded phosphate, sulphate, and carbonate of lime, muriate of soda, silex, magnesia, and oxides of iron and manganese. The whole of these substances bore a very small proportion to the hair, and varied in hair of different colours. Hair, therefore, appears to consist chiefly of an animal matter resembling coagulated albumen ; of an oil of various colours ; of sulphur, silex, carbonate and phosphate of lime ; and oxides of iron and manganese.

Feathers probably agree in composition with hair. The quill, Mr. Hatchett has shown, consists of coagulated albumen without any gelatine.

The composition of *wool* is not accurately known ; but from its forming a soap with pure alkalis, it probably consists of coagulated albumen.

We are equally ignorant of the true nature of silk. It is insoluble both in water and in alcohol, but dissolves in pure alkalis and acids. By the action of nitric acid it affords the peculiar substance already described under the name of the bitter principle.

SECTION IX.

Of the Substance of the Brain.

The medullary matter of the brain and nervous system appears to differ from all other organized substances. It was first examined by M. Thouret, with a view to explain why the brain was exempted from the change, observed in the bodies which were interred in the *Cimetière des Innocens.* Fourcroy afterwards added many important facts, and corrected M. Thouret in several particulars.

The medullary substance of the brain is of a soft consistence,

and forms, when agitated with water, a sort of emulsion, that passes through the finest sieves. This fluid is coagulated by a temperature of 160°, and a quantity of a substance resembling albumen is separated. The same coagulation is produced by acids; but the coagulum differs, in several respects, from that which takes place from the serum of the blood. On being boiled with alcohol, it loses about $\frac{1}{10}$ of its weight; but one third of the portion, which has been dissolved, is again deposited on cooling in the form of lamellated crystalline plates, resembling those which are obtained from biliary calculi, from spermaceti, or from adipocire; but differing from those substances in requiring a higher temperature for its fusion. The portion of medulla, which remains in solution, may be separated either by the addition of water or by evaporation.

The medulla of the brain, when exposed to the air, soon undergoes spontaneous decomposition; and evolves an acid, before it passes to the putrid state; but under water it may be kept a long time without any change. Nitric acid does not produce the same effects upon it, as on other animal substances. No nitrogen is separated; but, when the temperature is raised, a large quantity of carbonate of ammonia is disengaged, and oxalic acid is found in the retort.

Diluted sulphuric acid partly dissolves brain, and coagulates another part. The acid solution becomes black when concentrated by evaporation; sulphurous acid is generated; and crystals are formed which consist of sulphate of ammonia. Besides this salt, sulphates of ammonia and lime, phosphoric acid, and phosphates of soda and ammonia are found in the liquid.

When brain is dried at the temperature of boiling water, it coagulates and some water separates from it. When the heat is increased, ammonia is disengaged; which, uniting with carbonic acid formed at the same time, composes carbonate of ammonia. A portion of oil is obtained also, and sulphuretted and carburetted hydrogen gases are formed. In the retort a coal remains which affords traces of phosphates of lime and soda.

PART II.

DIRECTIONS FOR EXAMINING MINERAL WATERS, AND MINERAL BODIES IN GENERAL.

CHAPTER I.

ANALYSIS OF MINERAL WATERS.

[See note 39 at the end of this vol.]

THE complete and accurate analysis of mineral waters, and of mineral bodies in general, is one of the most difficult subjects of chemical manipulation, and requires a very extensive acquaintance with the properties and habitudes of a numerous class of substances. Long and attentive study of the science is therefore essential to qualify any one for undertaking exact and minute determinations of the proportion of the component parts of bodies. Such minuteness, however, is scarcely ever required in the experiments that are subservient to the ordinary purposes of life; a general knowledge of the composition of bodies being sufficient to assist in directing the most useful applications of them. I shall not attempt, therefore, to lay down rules for accurate analysis, but shall only describe such experiments as are suited to afford an insight into the kind, but not to decide the exact proportion, of the constituent principles of natural waters, and of mineral substances in general.

Before proceeding, however, to the analysis of a water, it is proper to inquire into its natural history, and to examine attentively its physical characters. The nature of the strata in the neighbourhood of the spring will often furnish useful suggestions respecting the contents of the water; the period of the year should be stated at which the analysis was performed; and whether after a rainy or dry season. The temperature of the water must be carefully observed, as it issues from the spring; and the quantity inquired into, which it yields in a given time. The sensible qualities of taste, smell, degree of transparency, &c. are also best ascertained at the fountain-head. The specific gravity of the water may be found by weighing a bottle, which is capable of containing a known weight of distilled water, at a certain temperature, filled with the water, under examination, at the same temperature. It

is proper, also, to examine, on the spot, the channel through which the water has flowed; to collect any deposite that may have been formed; and to investigate its nature.

The effects of heat on the water may be next tried.—Many waters lose their transparency when their temperature is raised, and let fall a considerable deposite. The quality of this may, in some degree, be conjectured from its appearance. If its colour be brownish yellow, it consists, either wholly or chiefly, of oxide of iron; if white, or nearly white, it is composed principally of the earthy carbonates. A mineral water, containing iron, deposites that metal also, when exposed to the atmosphere; and a thin pellicle forms on its surface, whether stagnant in a natural reservoir, or collected in a separate vessel. By this exposure, iron may be sometimes discovered in a water, though not easily detected at first; because it becomes farther oxidized, and more sensible to the action of tests. Sulphuretted hydrogenous waters deposite a sediment, even when preserved in a well-closed phial; the hydrogen quitting the sulphur, which settles in the form of a white powder.

SECTION I.

Examination of Mineral Waters by Re-agents.

WATER is never presented by nature in a state of complete purity. Even when collected as it descends in the form of rain, chemical tests detect in it a minute proportion of foreign ingredients. And when it has been absorbed by the earth, has traversed its different strata, and is retured to us by springs, it is found to have acquired various impregnations. The readiest method of judging of the contents of natural waters, is by applying what are termed tests, or re-agents; i. e. substances which, on being added to a water, exhibit, by the phenomena they produce, the nature of the saline, or other ingredients.—For example, if, on adding infusion of litmus to any water, its colour is changed to red, we infer, that the water contains an uncombined acid: if this change ensues, even after the water has been boiled, we judge that the acid is a fixed, and not a volatile one: and if, on adding the muriated barytes, a precipitate falls down, we safely conclude that the peculiar acid, present in the water, is either entirely or in part, the sulphuric acid. I shall first enumerate the tests generally employed in examining waters, and describe their application; and, afterwards, point out by what particular tests the substances, generally found in waters, may be detected.

In many instances, however, a mineral water may contain a saline, or other ingredient, but in such small quantity as to escape discovery by tests. It is therefore advisable to apply the tests of fixed substances to the water, after reducing its bulk one half, or more, by evaporation, as well as in its natural state.

The use of tests, or re-agents, has been employed by Mr. Kirwan to ascertain by a careful examination of the precipitate not only the *kind*, but the *quantity*, of the ingredients of mineral waters. This will be best understood from an example. It is an established fact, that 100 parts of crystallized muriate of soda, when completely decomposed by nitrate of silver, yield, as nearly as possible, 240 of precipitated muriate of silver. From the weight of the precipitate, separated by nitrate of silver from a given quantity of any water, it is therefore easy, when no other muriatic salt is present, to infer, what quantity of muriate of soda was contained in the water ; since every hundred grains of muriated silver indicate, pretty accurately, $41\frac{1}{2}$ of crystallized common salt. The same mode of estimation may be applied in various other instances ; and the rule for each individual case will be stated in the following description of the use of the various re-agents.

I.—*Infusion of Litmus, Syrup of Violets, &c.*

The infusion of litmus is prepared by steeping this substance, first bruised in a mortar, and tied up in a linen rag, in distilled water, which extracts its blue colour.

If the colour of the infusion tends too much to purple, it may be amended by a drop or two of solution of pure ammonia ; but of this no more must be added than is barely sufficient, lest the delicacy of the test should be impaired.

The syrup of violets is not easily obtained pure. The genuine syrup may be distinguished from the spurious by a solution of corrosive sublimate, which changes the former to green, while it reddens the latter. When it can be procured genuine, it is an excellent test of acids, and may be employed in the same manner as the infusion of litmus.

Paper stained with the juice of the March violet, or with that of the scrapings of radishes, answers a similar purpose. In staining paper for the purposes of a test, the paper must be used unsized ; or, if sized, it must previously be well washed with warm water ; because the alum, which enters into the composition of the size, will otherwise change the vegetable colour to red.

In the Philosphical Magazine, vol. i. page 180, may be found some recipes for other test liquors, invented by Mr. Watt.

Infusion of litmus is a test of most uncombined acids.

1. If the infusion redden the unboiled, but not the boiled water, under examination; or if the red colour, occasion by adding the infusion to a recent water, return to blue, on boiling; we may infer, that the acid is a volatile one, and most probably the carbonic acid. Sulphuretted hydrogen gas, dissolved in water, also reddens litmus, but not after boiling.

2. To ascertain whether the change be produced by carbonic acid or by sulphuretted hydrogen, when experiment shows that the reddening cause is volatile, add a little lime-water, or, in preference, barytic water. This, if carbonic acid be present, will occasion a precipitate, which will dissolve, with effervescence, on adding a little muriatic acid. Sulphuretted hydrogen may also be contained, along with carbonic acid, in the same water; which will be determined by the tests hereafter to be described.

3. Paper tinged with litmus is also reddened by the presence of carbonic acid, but regains its blue colour on drying. The mineral and fixed acids redden it permanently. That these acids, however, may produce their effect, it is necessary that they should be present in a sufficient proportion. (See Kirwan on Mineral Waters, page 40.) The dark blue paper, which is generally wrapped round loaves of refined sugar, is not discoloured by carbonic acid or sulphuretted hydrogen, but only by the stronger acids.

II.—*Infusion of Litmus reddened by Vinegar,—Spirituous Tincture of Brazil-wood,—Tincture of Turmeric, and Paper stained with each of these three Substances,—Syrup of Violets.*

All these different tests have one and the same object.

1. Infusion of litmus reddened by vinegar, or litmus paper reddened by vinegar, has its blue colour restored by pure alkalis and pure earths, and by carbonated alkalis and earths.

2. Turmeric paper and tincture are changed to a redish brown by alkalis, whether pure or carbonated, and by pure earths, but not by carbonated earths.

3. The red infusion of brazil-wood, and paper stained with it, become blue by alkalis and earths, and even by the latter when dissolved by an excess of carbonic acid. In the last-mentioned case, however, the change will either cease to appear, or will be much less remarkable, when the water has been boiled.

4. Syrup of violets, when pure, is, by the same causes, turned green ;* as is also paper stained with the juice of the violet, or with the scrapings of radishes.

III.—*Tincture of galls.*

Tincture of galls is the test generally employed for discovering iron ; with all the combinations of which it produces a black tinge, more or less intense according to the quantity of iron. The iron, however, in order to be detected by this test, must be in the state of red oxide, or, if oxidized in a less degree, its effect will not be apparent, unless after standing some time in contact with the air. By applying this test before and after evaporation, or boiling, we may know whether the iron be held in solution by carbonic acid, or by a fixed acid ; For,

1. If it produce its effect before the application of heat, and not afterward, carbonic acid is the solvent.

2. If after, as well as before, a mineral acid is the solvent.

3. If, by the boiling, a yellowish powder be precipitated, and yet galls still continue to strike the water black, the iron, as often happens, is dissolved both by carbonic acid and by a fixed acid. A neat mode of applying the gall-test was used by M. Klaproth, in his analysis of the Carlsbad water ; a slice of the gall-nut was suspended by a silken thread in a large bottle of the recent water, and so small was the quantity of iron, that it could only be discov-ered in water fresh from the spring, by a slowly formed and dark cloud, surrounding the re-agent. (Klaproth, vol. i. page 279.)

IV.—*Sulphuric Acid.*

1. Sulphuric acid discovers, by a slight effervescence, the pres-ence of carbonic acid, whether uncombined or united with alkalis or earths.

2. If lime be present, whether pure or uncombined, the addition of sulphuric acid occasions, after a few days, a white precipitate. If from a mineral water, which has been well boiled, the addition of sulphuric acid extricates sulphuretted hydrogen gas, Mr. Wes-trumb infers the presence of hydro-sulphuret of lime. In this

* According to Mr. Accum, syrup of violets, which has lost its colour by keeping, may be restored by agitation, during a few minutes, in contact with oxygen gas. In preference to the syrup, Mr. Descroizilles recom-mends as a test the *pickle* of violets, prepared by adding common salt to the expressed juice. *Annales de Chimie,* lxvii. 80 ; or Nicholson's Journal, xxv. 232.

case, sulphate of lime is precipitated. (Nicholson's Journal, xviii. 40.)

3. Barytes is precipitated instantly, in the form of a white powder.

4. Nitric and muriatic salts, in a dry state, or dissolved in very little water, on adding sulphuric acid, and applying heat, are decomposed ; and if a stopper, moistened with solution of pure ammonia, be held over the vessel, white clouds will appear. For distinguishing whether nitric or muriatic acid be the cause of this appearance, rules will be given hereafter.

V.—*Nitric and Nitrous Acids.*

These acids, if they occasion effervescence, give the same indications as the sulphuric. The fuming red nitrous acid has been recommended as a test distinguishing between hepatic waters that contain hydro-sulphuret of potash, and those that contain only sulphuretted hydrogen gas. In the former case, a precipitate ensues on adding nitrous acid, and a very fetid smell arises ; in the latter, a slight cloudiness only appears, and the smell of the water becomes less disagreeable. If a water, after boiling, gives a precipitate of sulphur, on adding nitrous acid, Westrumb concludes that this is owing to hydro-sulphuret of lime.

VI.—*Oxalic Acid and Oxalates.*

The oxalic acid is a most delicate test of lime, which it separates from all its combinations.

1. If a water, which is precipitated by oxalic acid, become milky on adding a watery solution of carbonic acid, or by blowing air through it from the lungs, by means of a quill or glass tube, we may infer, that pure lime (or barytes, which has never yet been found pure in waters) is present.

2. If the oxalic acid occasion a precipitate before, but not after boiling, the lime is dissolved by an excess of carbonic acid.

3. If after boiling, by a fixed acid. A considerable excess of any of the mineral acids, however, prevents the oxalic acid from occasioning a precipitate, even though lime be present ; because some acids decompose the oxalic, and others, dissolving the oxalate of lime, prevent it from appearing. (See Kirwan on Waters, page 88.)

The oxalate of ammonia, or of potash (which may easily be formed by saturating the respective carbonates of these alkalis with a solution of oxalic acid,) are not liable to the above objection, and

are preferable, as re-agents, to the uncombined acid. Yet even these oxalates fail to detect lime when super-saturated with muriatic or nitric acids ; and, if such an excess be present, it must be saturated, before adding the test, with pure ammonia. A precipitation will then be produced.

The quantity of lime, contained in the precipitate, may be known, by first calcining it with access of air, which converts the oxalate into a carbonate ; and by expelling, from this last, its carbonic acid, by calcination, with a strong heat, in a covered crucible. According to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160° Fahrenheit.

The fluate of ammonia, recommended by Scheele, I find to be a most delicate test of lime. It may be prepared by adding carbonate of ammonia to diluted fluoric acid, in a leaden vessel, observing that there be a small excess of acid.

VII.—*Pure Alkalis and Carbonated Alkalis.*

1. The pure fixed alkalis precipitate all earths and metals, whether dissolved by volatile or fixed menstrua, but only in certain states of dilution ; for example, sulphate of alumine may be present in water, in the proportion of four grains to 500, without being discovered by pure fixed alkalis. As the alkalis precipitate so many substances, it is evident that they cannot afford any very precise information, when employed as re-agents. From the colour of the precipitate, as it approaches to a pure white, or recedes from it, an experienced eye will judge, that the precipitated earth contains less or more of metallic admixture ; and its precise composition must be ascertained by rules which will presently be given.

2. Pure fixed alkalis also decompose all salts with basis of ammonia, which becomes evident by its smell (unless the salts are dissolved in much water,) and also by the white fumes it exhibits when a stopper, moistened with muriatic acid, is brought near.

3. Carbonates of potash and of soda have similar effects.

4. Pure ammonia precipitates all earthy and metallic salts. Beside this property, it also imparts a deep blue colour to any liquid that contains copper or nickel in a state of solution ; the precipitated oxides of those metals being re-dissolved by an excess of the volatile alkali.

5. Carbonate of ammonia has the same properties, except that it does not precipitate magnesia from its combinations. Hence, to ascertain whether this earth be present in any solution, add the

carbonate of ammonia till no farther precipitation ensues ; filter the liquor ; raise it nearly to 212° Fahrenheit ; and then add pure ammonia. If any precipitation now occurs, we may infer the presence of magnesia. It must be acknowledged that zircon, yttria, and glucine, would escape discovery by this process ; but they have never yet been found in mineral waters ; and their presence can scarcely be expected.

VIII.—*Lime-Water.*

1. Lime-water is applied to the purposes of a test, chiefly for detecting carbonic acid. Let any liquor supposed to contain this acid be mixed with an equal bulk of lime-water. If carbonic acid be present, either free or combined, a precipitate will immediately appear, which, on adding a few drops of muriatic acid will again be dissolved with effervescence.

2. Lime-water will also show the presence of corrosive sublimate by a brick-dust coloured sediment. If arsenous acid (common arsenic) be contained in a liquid, lime-water, when added, will occasion a precipitate, consisting of lime and arsenous acid, which is very difficultly soluble in water. This precipitate, when mixed up with oil, and laid on hot coals, yields the well known garlic smell of arsenic.

IX.—*Pure Barytes, and its Solution in Water.*

1. A solution of pure barytes is even more effectual than lime-water in detecting the presence of carbonic acid, and is much more portable and convenient ; since, from the crystals of this earth, the barytic solution may at any time be immediately prepared. In discovering carbonic acid, the solution of barytes is used similarly to lime-water, and if this acid be present, gives, in like manner, a precipitate soluble with effervescence in dilute muriatic acid.

2. The barytic solution is also a most sensible test of sulphuric acid and its combinations, which it indicates by a precipitate not soluble in muriatic acid.—Pure strontites has similar effects as a test. The quantity of the precipitated substance, indicated by the weight of the precipitate, will be stated in No. XV.

X.—*Metals.*

1. Of the metals, silver and mercury are tests of the presence of hydro-sulphurets, and of sulphuretted hydrogen gas. If a little quicksilver be put into a bottle containing water impregnated with

either of these substances, its surface soon acquires a black film, and, on shaking the bottle, a blackish powder separates from it. Silver is speedily tarnished by the same cause.

2. The metals may be used also as tests of each other, on the principle of elective affinity. Thus, for example, a polished iron plate, immersed in a solution of sulphate of copper, soon acquires a coat of this metal ; and the same in other similar examples.

XI.—*Sulphate of Iron.*

This is the only one of the sulphates, except that of silver, applicable to the purposes of a test. When used with this view, it is generally employed for ascertaining the presence of oxygen gas, of which a natural water may contain a small quantity.

A water, suspected to contain this gas, may be mixed with a little recently-dissolved sulphate of iron, and kept corked up, in a phial completely filled by the mixture. If an oxide of iron be precipitated in the course of a few days, the water may be inferred to contain oxygen gas.

XII.—*Sulphate, Nitrate, and Acetate of Silver.*

These solutions are all in some measure applicable to similar purposes.

1. They are peculiarly adapted to the discovery of muriatic acid and of muriates. For the silver, quitting its solvent, combines with the muriatic acid, and forms a flaky precipitate, which, at first, is white, but, on exposure to the sun's light, acquires a blueish, and finally a black colour. This precipitate, dried and fused by a gentle heat, Dr. Black states to contain, in 1000 parts, as much muriatic acid as would form $425\frac{1}{2}$ of crystallized muriate of soda, which estimate scarcely differs at all from that of Klaproth. The same quantity of muriate of silver (1000 parts) indicates, according to Kirwan, $454\frac{3}{4}$ of muriate of potash. Dr. Marcet's experiments and my own indicate a larger product of muriate of silver from the decomposition of dry muriate of soda, *viz.* not less than 240 grains from 100 of common salt. Hence 100 grains of fused muriate of silver denote 41.6 of muriate of soda, and about 19 grains of muriatic acid. A precipitation, however, may arise from other causes, which it may be proper to state.

2. The solutions of silver in acids are precipitated by carbonated alkalis and earths. The agency of the alkalis and earths may, however, be prevented, by previously saturating them with a few drops of the same acid in which the silver is dissolved.

3. The nitrate and acetate of silver are decomposed by the sulphuric and sulphurous acids ; but this may be prevented by adding, previously, a few drops of nitrate or acetate of barytes, and, after allowing the precipitate to subside, the clear liquor may be decanted, and the solution of silver added. Should a precipitation now take place, the presence of muriatic acid, or some one of its combinations, may be suspected. To remove uncertainty, whether a precipitation be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed, which, when no uncombined alkali or earth is present, is affected only by the latter acid. According to Professor Pfaff, one part of muriatic acid of the specific gravity, 1.15, diluted with 70,000 parts of water, barely exhibits a slight opaline tinge, when tested with nitrate of silver : and, when diluted with 80,000 parts of water, it is not affected at all. (Nicholson's Journal, xvii. 361.)

4. The solutions of silver are also precipitated by sulphuretted hydrogen, and by hydro-sulphurets ; but the precipitate is then reddish, or brown, or black ; or it may be, at first, white, and afterwards become speedily brown or black. It is soluble, in great part, in dilute nitrous acid, which is not the case if occasioned by muriatic or sulphuric acid.

5. The solutions of silver are precipitated by extractive matter ; but, in this case, also, the precipitate has a dark colour, and is soluble in nitrous acid.

XIII.—*Nitrate and Acetate of Lead.*

1. Acetate of lead, the most eligible of these two tests, is precipitated by sulphuric and muriatic acids ; but, as of both these we have much better indicators, I do not enlarge on its application to this purpose.

2. The acetate is also a test of sulphuretted hydrogen and of hydro-sulphurets of alkalis, which occasion a black precipitate ; and, if a paper, on which characters are traced with a solution of acetate of lead, be held over a portion of water containing sulphuretted hydrogen gas, they are soon rendered visible ; especially when the water is a little warmed.

3. The acetate of lead is employed in the discovery of uncombined boracic acid, a very rare ingredient of waters. To ascertain whether this be present, some cautions are necessary. (*a*) The uncombined alkalis and earths (if any be suspected) must be saturated with acetic or acetous acid. (*b*) The sulphates must be decomposed by acetate or nitrate of barytes, and the muriates

by acetate or nitrate of silver. The filtered liquor, if boracic acid be contained in it, will continue to give a precipitate, which is soluble in nitric acid of the specific gravity 1.3.

4. Acetate of lead is said, also, by Pfaff to be a very delicate test of carbonic acid; and that it renders milky water, which contains the smallest possible quantity of this acid.

XIV.—*Nitrate of Mercury prepared with and without Heat.*

This solution, differently prepared, is sometimes employed as a test.

1. The solution of nitrate of mercury, prepared without heat,* has been found by Pfaff to be a much more sensible test of muriatic acid than nitrate of silver. Its sensibility, indeed, is so great, that 1 part of muriatic acid, of the specific gravity 1.50, diluted with 300,000 parts of water, is indicated by a slightly dull tint ensuing on the addition of the test.

2. It is at the same time, the most sensible test of ammonia, one part of which, with 30,000 parts of water, is indicated by a slight blackish yellow tint, on adding the nitrate of mercury.

3. The nitrate of mercury is also precipitated by highly diluted phosphoric acid; but the precipitate is soluble in an excess of phosphoric or nitric acid, which is not the case if it has been occasioned by muriatic acid.

XV.—*Muriate, Nitrate, and Acetate of Barytes.*

1. These solutions are all most delicate tests of sulphuric acid and of its combinations, with which they give a white precipitate, insoluble in dilute muriatic acid. They are decomposed, however, by carbonates of alkali; but the precipitate occasioned by carbonates is soluble in dilute muriatic or nitric acid, with effervescence, and may even be prevented by adding, previously, a few drops of the same acid as that contained in the barytic salt, which is employed.

One hundred grains of dry sulphate of barytes contain (according to Klaproth, vol. i. page 168,) about $45\frac{1}{2}$ of sulphuric acid of the specific gravity 1850; according to Clayfield (Nicholson's Journal, 4to. iii. 38,) 33 of acid, of the specific gravity 2240; according to Thenard, after calcination, about 25; and, according to Mr. Kirwan, after ignition, 23.5 of real acid. The same chemist states, that 170 grains of ignited sulphate of barytes denote 100 of dried sulphate of soda; while 136.36 of the same substance in-

* See chap. xviii. sect 4, vi.

dicate 100 of dry sulphate of potash; and 100 parts result from the precipitation of 52.11 of sulphate of magnesia.

From Klaproth's experiments, it appears, that 1000 grains of sulphate of barytes indicate 595 of desiccated sulphate of soda, or 1416 of the crystallized salt. The same chemist has shown, that 100 grains of sulphate of barytes are produced by the precipita- · tion of 71 grains of sulphate of lime, of ordinary dryness. The results of my own experiments are stated in vol. i. page 253. From these it follows, that 100 grains of ignited sulphate of bary- tes denote 57 of calcined sulphate of lime; or 73 of the same sul- phate, dried by a temperature of only 160° Fahrenheit. Desic- cated sulphate of magnesia, when decomposed by muriate of ba- rytes, affords twice its weight of the barytic sulphate.

2. Phosphoric salts occasion a precipitate also, which is soluble in muriatic acid without effervescence.

XVI.—*Prussiates of Potash and of Lime.**

Of these two, the prussiate of potash is the most eligible. When pure, it does not speedily resume a blue colour on the ad- dition of an acid, nor does it *immediately* precipitate muriate of barytes.

Prussiate of potash is a very sensible test of iron, with the so- lutions of which in acids it produces a prussian blue precipitate, in consequence of a double elective affinity. To render its effect more certain, however, it may be proper to add, previously, to any water suspected to contain iron, a little muriatic acid, with a view to the saturation of uncombined alkalis or earths, which, if pres- ent, prevent the detection of very minute quantities of iron.

1. If a water, after boiling and filtration, does not afford a blue precipitate, on the addition of prussiate of potash, the solvent of the iron may be inferred to be a volatile one, and probably the carbonic acid.

2. Should the precipitation ensue in the boiled water, the sol- vent is a fixed acid, the nature of which must be ascertained by other tests.

In using the prussian test for the discovery of iron, considerable caution is necessary, in order to attain accurate results. The prussiate should, on all occasions, be previously crystallized; and the quantity of oxide of iron, essential to its constitution, or at least an invariable accompaniment, should be previously ascer- tained in the following manner. Expose a known weight of the

* The triple prussiates are to be understood in this place.

crystallized salt to a low red-heat in a silver crucible. After fus-
ing and boiling up, it will become dry, and will then blacken.
Let it cool; wash off the soluble part; collect the rest on a filter;
dry it, and again calcine it with a little wax. Let it be again
weighed, and the result will show the proportion of oxide of iron
present in the salt which has been examined. This varies from
22 to 30 and upwards *per cent.* When the test is employed for
discovering iron, let a known weight of the salt be dissolved in a
given quantity of water; add the solution gradually; and observe
how much is expended in effecting the precipitation. Before
collecting the precipitate, warm the liquid, which generally throws
down a farther portion of prussian blue. Let the whole be wash-
ed and dried, and then calcined with wax. From the weight of
the oxide obtained, deduct that quantity, which, by the former
experiment, is known to be present in the prussiate that has been
added; and the remainder will denote the quantity of oxide of
iron, present in the liquid under examination.

3. Besides iron, the prussiated alkalis also precipitate muriate
of alumine. No conclusion, therefore, can be deduced, respecting
the non-existence of muriate of alumine, from any process, in
which the prussic test has previously been used. It will, there-
fore, be proper, if a salt of alumine be indicated by other tests, to
examine the precipitate effected by prussiate of potash. This
may done by repeatedly boiling it to dryness with muriatic acid,
which takes up the alumine, and leaves the prussiate of iron.
From the muriatic solution, the alumine may be precipitated by a
solution of carbonate of potash.

4. According to Klaproth (ii. 55,) solutions of yttria (which
earth, however, is not likely to be present in any mineral water)
afford, with the prussian test, a white precipitate, passing to pearl-
grey, which consists of prussiate of yttria. This precipitate dis-
appears on adding an acid, and hence may be separated from prus-
siated iron. The same accurate chemist, states that the prussian
test has no action on salts with base of glucine (ib.) but that it
precipitates zircon from its solutions. (ii. 214.)

The prussiated alkalis decompose, also, all metallic solutions
excepting those of gold, platina, iridium, rhodium, osmium, and
antimony.

XVII.—*Succinate of Soda and of Ammonia.*

1. The succinate of soda was first recommended by Gehlen,
and afterwards employed by Klaproth (Contributions, ii. 48) for

the discovery and separation of iron. The salt with base of am-
monia has also been used for a similar purpose by Dr. Marcet,
physician to Guy's Hospital, in a skilful analysis of the Brighton
chalybeate, which is published in the new edition of Dr. Saun-
ders's Treatise on Mineral Waters.

The succinic test is prepared by saturating carbonate of soda
or ammonia with this acid, already described, chap. xix. sect. 8.
In applying the test, it is necessary not to use more than is suffi-
cient for the purpose; because an excess of it re-dissolves the
precipitate. The best mode of proceeding is to heat the solution
containing iron, and to add gradually the solution of succinate, un-
til it ceases to produce any effect. A brownish precipitate is ob-
tained, consisting of succinate of iron. This, when calcined with
a little wax, in a low red-heat, gives an oxide of iron, containing
about 70 *per cent.* of the metal. From Dr. Marcet's experiments,
it appears that 100 grains of iron, dissolved in sulphuric acid, then
precipitated by the succinate test, and afterwards burned with wax,
give 148 of oxide of iron; that is, 100 grains of the oxide indicate
about $67\frac{1}{2}$ of metallic iron.

2. The succinates, however, it is stated by Dr. Marcet and Mr.
Ekeberg, precipitate alumine, provided there be no considerable
excess of acid in the aluminous salt. On magnesia it has no ac-
tion, and hence may be successfully employed in the separation of
these two earths. If 100 parts of octohedral crystals of alum be
entirely decomposed by succinate of ammonia, they give precisely
12 parts of alumine calcined in a dull red-heat. The succinate of
ammonia, it is stated by Mr. Ekeberg (*Journ. des Mines*, No. 70,)
precipitates glucine; and the same test, according to Klaproth
(ii. 214,) throws down zircon from its solutions.

XVIII.—*Phosphate of Soda.*

An easy and valuable method of precipitating magnesia has
been suggested by Dr. Wollaston. It is founded on the property
which fully neutralized carbonate of ammonia possesses; first to
dissolve the carbonate of magnesia, formed when it is added to the
solution of a magnesian salt, and afterwards to yield the earth to
phosphoric acid, with which and ammonia it forms a triple salt
For this purpose, a solution of carbonate of ammonia, prepared
with a portion of that salt which has been exposed, spread on a pa-
per, for a few hours to the air, is to be added to the solution of the
magnesian salt sufficiently concentrated; or to a water suspected
to contain magnesia, after being very much reduced by evapora-

tion. No precipitate will appear, till a solution of phosphate of soda is added, when an abundant one will fall down. Let this be dried in a temperature not exceeding 100° Fahrenheit. One hundred grains of it will indicate 19 of pure magnesia; about 66 of muriate of magnesia; and 62 of desiccated, or double that quantity of crystallized, sulphate of magnesia.

XIX.—*Muriate of Lime.*

Muriate of lime is principally of use in discovering the presence of alkaline carbonates, which, though they very rarely occur, have sometimes been found in mineral waters. Carbonate of potash exists in the waters of Aix-la-Chapelle; that of soda, in the water of a few springs and lakes; and the ammoniacal carbonate was detected by Mr. Cavendish in the waters of Rathbone-place. Of all the three carbonates, muriate of lime is a sufficient indicator; for those salts separate from it a carbonate of lime, soluble with effervescence in muriatic acid.

With respect to the discrimination of the different alkalis, potash may be detected by the nitro-muriate of platina, which distinctly and immediately precipitates that alkali and its compounds, and is not affected by soda. Carbonate of ammonia may be discovered by its smell; and by its precipitating a neutral salt of alumine while it has no action apparently on magnesian salts.

To estimate the proportion of an alkaline carbonate present in any water, saturate with sulphuric acid, and note the weight of real acid which is required. Now 100 grains of real sulphuric acid saturate 121.48 potash, and 78.32 soda.

XX.—*Solution of Soap in Alcohol.*

This solution may be employed to ascertain the comparative hardness of waters. With distilled water it may be mixed, without any change ensuing; but if added to a hard water, it produces a milkiness, more considerable as the water is less pure; and, from the degree of this milkiness, an experienced eye will derive a tolerable indication of the quality of the water. This effect is owing to the alkali quitting the oil, whenever there is present in a water any substance, for which the alkali has a stronger affinity than it has for oil. Thus all uncombined acids, and all earthy and metallic salts, decompose soap, and occasion that property in waters, which is termed hardness.

XXI.—*Alcohol.*

Alcohol, when mixed with any water, in the proportion of about

an equal bulk, precipitates all the salts which it is incapable of dis-
solving. (See Kirwan on Waters, page 187.)

XXII.—*Hydro-Sulphuret of Ammonia.*

This and other sulphurets, as well as water saturated with sul-
phuretted hydrogen, may be employed in detecting lead and arse-
nic ; with the former of which they give a black, and with the lat-
ter a yellowish precipitate. As lead and arsenic, however, are
never found in natural waters, I shall reserve, for another occa-
sion, what I have to say of the application of these tests.

TABLE,

Showing the Substances that may be expected in Mineral Waters,
and the Means of detecting them.

Acids in general. Infusion of litmus.—Syrup of violets, I.

Acid, boracic. Acetate of lead, XIII. 3.

Acid, carbonic. Infusion of litmus, I. 1. 2.—Lime-water, VIII.
1.—Barytic water, IX. 1.

Acid, muriatic. Nitrate and acetate of silver, XII. Nitrate of
mercury, XIV.

Acid, nitric. Sulphuric acid, IV. 4.

Acid, phosphoric. Solutions of barytes, XV. 2. Nitrate of mer-
cury, XIV. 3.

Acid, sulphurous. By its smell,—and destroying the colour of
litmus, and of infusion of red roses :—by the cessation of the
smell a few hours after the addition of the black oxide of manga-
nese.

Acid, sulphuric. Solution of pure barytes, IX. Barytic salts,
XV. Acetate of lead, XII.

Alkalis in general. Vegetable colours, II. Muriate of lime,
XIX.

Alumine dissolved by acids. Succinates, XVII.

Ammonia, by its smell, and tests, II. Nitrate of mercury,
XIV. 2.

Barytes, and its compounds, by sulphuric acid, IV.

Carbonates in general. Effervesce on adding acids.

Earths dissolved by carbonic acid. By a precipitation on boil-
ing ;—by pure alkalis, VII.

Hydro-sulphuret of lime. Sulphuric acid, IV. Nitrous a-
cid, V.

Iron dissolved by carbonic acid. Tincture of galls, III. 1.
Prussiate of potash, XVI. 1. Succinate of ammonia, XVII.

Iron dissolved by sulphuric acid. Same tests, III. 3. XVI. 2. XVII.

Lime in a pure state. Water saturated with carbonic acid. Blowing air from the lungs. Oxalic acid, VI.

Lime dissolved by carbonic acid. Precipitation on boiling.— Caustic alkalis, VII. Oxalic acid, VI.

Lime dissolved by sulphuric acid. Oxalate of ammonia, VI. Barytic solutions, IX. and XV.

Magnesia dissolved by carbonic acid. Precipitation on boiling, —the precipitate soluble in dilute sulphuric acid.

Magnesia dissolved by other acids. Precipitated by pure ammonia, not by the carbonate, VII. 5. Phosphate of soda, XVII.

Muriates of alkalis. Solutions of silver, XII.

——— *of lime.* Solutions of silver, XII. Oxalic acid and oxalate of ammonia, VI.

Sulphates in general. Barytic solutions, IX. and XV. —Acetate of lead, XIII.

Sulphate of alumine. Barytic solutions, IX. and XV.—A precipitate by carbonate of ammonia not soluble in acetous acid, but soluble in pure fixed alkalis by boiling. Succinates XVII. 2.

Sulphate of lime. Barytic solutions, IX. and XV.—Oxalic acid, and oxalates, VI.—A precipitate by alkalis not soluble in dilute sulphuric acid.

Sulphurets of alkalis. Polished metals, X. Smell on adding sulphuric or muriatic acid. Nitrous acid, V.

Sulphuretted hydrogen gas. By its smell. Infusion of litmus, I. Polished metals, X. Acetate of lead, XIII. 2.*

SECTION II.

Analysis of Waters by Evaporation.

BEFORE proceeding to the evaporation of any natural water, its gaseous contents must be collected. This may be done by filling with the water a large glass bottle, capable of holding about 50 cubical inches, and furnished with a ground stopper and bent tube. The bottle is to be placed, up to its neck, in a tin kettle filled with a saturated solution of common salt, which must be kept boiling for an hour or two, renewing, by fresh portions of hot water, what

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* The vapour of putrefying animal or vegetable matter dissolved in water, according to Klaproth, vol. i. page 590, often gives a deceptive indication of sulphuretted hydrogen.

is lost by evaporation. The disengaged gas is conveyed, by the bent tube, into a graduated jar, filled with, and inverted in, mercury, where its bulk is to be determined. On the first impression of the heat, however, the water will be expanded, and portions will continue to escape into the graduated jar, till the water has obtained its maximum of temperature. This must be suffered to escape, and its quantity be deducted from that of the water submitted to experiment.

In determining, with precision, the quantity of gas, it is necessary to attend to the state of the barometer and thermometer, and to other circumstances already enumerated, vol. i. page 119. Rules for reducing observations made under different states of the barometer and thermometer, to a mean standard, will be given in the Appendix. If a considerable proportion of gas be contained in a mineral water, the most commodious method of receiving it is into a small gazometer.

The gases, most commonly found in mineral waters, are *carbonic acid ; sulphuretted hydrogen ; nitrogen gas ; oxygen gas ;* and, in the neighbourhood of volcanoes only, *sulphurous acid gas.*

To determine the proportion of the gases, constituting any mixture obtained from a mineral water in the foregoing manner, the following experiments may be made. If the use of re-agents has not detected the presence of sulphuretted hydrogen, and there is reason to believe, from the same evidence, that carbonic acid forms a part of the mixture, let a graduated tube be nearly filled with it over quicksilver. Pass up a small portion of solution of potash, and agitate this in contact with the gas. The amount of the diminution will show how much carbonic acid has been absorbed ; and, if the quantity submitted to experiment, was an aliquot part of the whole gas obtained, it is easy to infer the total quantity present in the water. The unabsorbable residuum consists, most probably, of oxygen and azotic gases ; and the proportion of these two is best learned by the use of Dr. Hope's eudiometer. (See vol. i. page 134.)

If sulphuretted hydrogen be present, along with carbonic acid, the separation of these two is a problem of some difficulty. Mr. Kirwan recommends that a graduated glass vessel, completely filled with the mixture, be removed into a vessel containing nitrous acid. This instantly condenses the sulphuretted hydrogen, but not the carbonic acid gas. I apprehend, however, that a more eligible mode will be found to be, the condensation of the sulphuretted hydrogen by oxy-muriatic acid gas (obtained from muriatic

acid and hyper-oxy-muriate of potash ;) adding the latter gas ve-
ry cautiously, as long as it produces any condensation. Or, per-
haps a bettter plan of effecting the separation will be the following :
Half fill a graduated phial with the mixed carbonic acid and sul-
phuretted hydrogen gases, and expel the rest of the water by oxy-
muriatic acid gas. Let the mouth of the bottle be then closed
with a well-ground stopper, and let the mixture be kept twenty-
four hours. Then withdraw the stopper under water, a quantity
of which fluid will immediately rush in. Allow the bottle to stand
half an hour without agitation. The redundant oxy-muriatic acid
gas will thus be absorbed ; and very little of the carbonic acid will
disappear. Supposing that, to ten cubic inches of the mixed gas-
es, ten inches of oxy-muriatic gas have been added, and that, af-
ter absorption by standing over water, five inches remain : the re-
sult of this experiment shows, that the mixture consisted of equal
parts of sulphuretted hydrogen and carbonic acid gases.

Mr. Westrumb ascertains the proportion of sulphuretted hydro-
gen and carbonic acid gases, by the following method. He intro-
duces a known quantity of the water under examination into a
glass vessel, from which proceeds a curved tube, terminating in a
long cylinder, filled with lime-water. The gas is expelled by
heat, and the precipitate collected. Every 20 grains indicate 10
cubic inches of carbonic acid. To determine the quantity of sul-
phuretted hydrogen, the same experiment is repeated, substituting
a solution of super-acetate of lead. Hydro-sulphuret of lead is
formed, in the proportion of 19 grains to 10 cubic inches of gas.
This method, for several reasons which it would take too much
room to state, is perhaps inferior to the one which I have just pro-
posed.

Whenever this complicated admixture of gases occurs, as in
the case of the Harrowgate-water, it is advisable to operate sepa-
rately on two portions of gas, with the view to determine, by the
one, the quantity of carbonic acid and sulphuretted hydrogen ; and
that of nitrogen and oxygen by the other. In the latter instance,
remove both the absorbable gases by caustic potash ; and exam-
ine the remainder in the manner already directed.

Nitrogen gas sometimes occurs in mineral waters, almost in an
unmixed state. When this happens, the gas will be known by
the characters already described as belonging to it, vol. i. page
129. Sulphurous acid gas may be detected by its peculiar smell
of burning brimstone, and by its discharging the colour of an in-

fusion of roses, which has been reddened by the smallest quantity of any mineral acid adequate to the effect.

The vessels employed for EVAPORATION, should be of such materials as are not likely to be acted on by the contents of the water. I prefer those of unglazed biscuit ware, made by Messrs. Wedgwood; but, as their surface is not perfectly smooth, and the dry mass may adhere so strongly as not to be easily scraped off, the water, when reduced to about one tenth or less, may be transferred, with any deposite that may have taken place, into a smaller vessel of glass. Here let it be evaporated to dryness.

(*a*) The dry mass, when collected and accurately weighed, is to be put into a bottle, and alcohol poured on it, to the depth of an inch. After having stood a few hours, and been occasionally shaken, pour the whole on a filter, wash it with a little more alcohol and dry and weigh the remainder.

(*b*) To the undissolved residue, add eight times its weight of cold distilled water; shake the mixture frequently; and, after some time, filter; ascertaining the loss of weight.

(*c*) Boil the residuum, for a quarter of an hour, in somewhat more than 500 times its weight of water, and afterwards filter.

(*d*) The residue, which must be dried and weighed, is no longer soluble in water or alcohol. If it has a brown colour, denoting the presence of iron, let it be moistened with water, and exposed to the sun's rays for some weeks.

I. The solution in alcohol (*a*) may contain one or all of the following salts : Muriates of lime, magnesia, or barytes ; or nitrates of the same earths. Sometimes, also, the alcohol may take up a sulphate of iron, in which the metal is highly oxidized, as will appear from its redish brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness; weigh the residuum; add about half its weight of strong sulphuric acid; and apply a moderate heat. The muriatic or nitric acid will be expelled, and will be known by the colour of their fumes ; the former being white, and the latter orange coloured.

2. To ascertain whether lime or magnesia be the basis of the salts, let the heat be continued till no more fumes arise, and let it then be raised, to expel the excess of sulphuric acid. To the dry mass, add twice its weight of distilled water. This will take up the sulphate of magnesia, and leave the sulphate of lime. The two sulphates may be separately decomposed, by boiling with three or four times their weight of carbonate of potash. The car-

bonates of lime and magnesia, thus obtained, may be separately dissolved in muriatic acid, and evaporated. The weight of the dry salts will inform us how much of each the alcohol had taken up. Lime and magnesia may also be separated by the use of the phosphate of soda, applied in the manner already described in the preceding section, No. XVIII.

The presence of barytes, which is very rarely to be expected, may be known by a precipitation ensuing on adding sulphuric acid to a portion of the alcoholic solution, which has been diluted with 50 or 60 times its bulk of pure water.

II. The watery solution (*b*) may contain a variety of salts, the accurate separation of which from each other is a problem of considerable difficulty.

1. The analysis of this solution may be attempted by crystallization. For this purpose, let one half be evaporated by a very gentle heat, not exceeding 80° or 90°. Should any crystals appear on the surface of the solution, while hot, in the form of a pellicle, let them be separated and dried on bibulous paper. These are muriate of soda or common salt. The remaining solution, on cooling very gradually, will, perhaps, afford crystals distinguishable by their form and other qualities. When various salts, however, are contained in the same solution, it is extremely difficult to obtain them sufficiently distinct to ascertain their kind.

2. The nature of the saline contents must, therefore, be examined by tests, or re-agents.

The presence of an uncombined alkali will be discovered by the stained papers (page 223,) and of acids by the tests (page 222.) The vegetable alkali, or potash, may be distinguished from the mineral, or soda, by saturation with sulphuric acid, and evaporation to dryness ; the sulphate of soda being much more soluble than that of potash ; or, by supersaturation, with the tartarous acid, which gives a soluble salt with soda, but not with potash. Muriate of platina, also, is an excellent test of potash and its combinations ; for, with the smallest portion of this alkali, or any of its salts, it forms a distinct and immediate precipitate ; while it is not at all affected by the mineral alkali or its compounds.

If neutral salts be present in the solution, we have to ascertain both the nature of the acid and of the basis. This may be done by attention to the rules already given for the application of tests, which it is unnecessary to repeat in this place.

III. The solution by boiling water contains scarcely any thing besides sulphate of lime.

IV. The residuum (*d*) is to be digested in distilled vinegar, which takes up magnesia and lime, but leaves, undissolved, alumine and highly oxidized iron. Evaporate the solution to dryness. If it contain acetate of lime only, a substance will be obtained which does not attract moisture from the air ; if magnesia be present, the mass will deliquiate. To separate the lime from the magnesia, proceed as in I.

The residue, insoluble in acetous acid, may contain alumine, iron, and silex. The two first may be dissolved by muriatic acid, from which the iron may be precipitated first by prussiate of potash, and the alumine afterward by a fixed alkali.

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CHAPTER II.

EXAMINATION OF MINERALS.

SECTION I.

General Directions.

THE chemical analysis of minerals is attended even with greater difficulties than that of natural waters ; and it would require not only a separate work, but one of considerable extent, to comprehend rules for determining the proportions of all possible combinations. On the present occasion, I mean only to offer a few general directions for attaining such a knowledge of the composition of mineral bodies, as may enable the chemical student to refer them to their proper place in a mineral arrangement, and to judge whether or not they may admit of application to the uses of common life. Those who are solicitous to become adepts in the art of mineral analysis, may read attentively the numerous papers of Vauquelin, Hatchett, and other skilful analysts, dispersed through various chemical collections ; and also an admirable work of M. Klaproth, lately translated into English, entitled, " Analytical Essays towards improving the Chemical Knowledge of Minerals," 2 vols. 8vo. published by Cadell and Davies, 1801.

The great variety of mineral bodies, which nature presents in the composition of this globe, have been classed by late writers under a few general divisions. They may be arranged under four heads. 1st, EARTHS ; 2d, SALTS ; 3d, INFLAMMABLE FOSSILS ; and, 4th, METALS, and their ores.

I. EARTHS.—The formation of such a definition of earths as would apply exactly to the bodies defined, and to no others, is at-

tended with considerable difficulty, and indeed has never yet been effected. It would lead me into too long a discussion, to comment, in this place, on the definitions that have been generally offered, and to state the grounds of objection to each of them. Sensible, therefore, that I am unable to present an unexceptionable character of earthy bodies, I shall select such a one as may be sufficient for the less accurate purpose of general distinction.

" The term earth," says Mr. Kirwan, " denotes a tasteless, inodorous, dry, brittle, uninflammable substance, whose specific gravity does not exceed 4.9 (*i. e.* which is never five times heavier than water,) and which gives no tinge to borax in fusion." After stating some exceptions to this definition, afforded by the strong taste of certain earths, and the solubility of others, he adds, " Since, however, a line must be drawn between salts and earths, I think it should begin where solution is scarcely perceptible ; salts terminating, and earths, in strictness, commencing, where the weight of the water, requisite for the solution, exceeds that of the solvent 1000 times. But, not to depart too widely from the commonly received import of words that are in constant use, substances that require 100 times their weight of water to dissolve them, and have the other sensible properties of earths, may be so styled in a loose and popular sense."

The simple, or primitive earths, are those which cannot be resolved into more remote principles. Such are lime, argill, magnesia, &c.

The compound earths are composed of two or more primitive earths, united chemically together. Sometimes the union of an earth with an acid constitutes what is vulgarly called an earth ; as in the examples of sulphate of lime, fluate of lime, &c.

II. SALTS.—Under this head Mr. Kirwan arranges " all those substances that require less than 100 times their weight of water to dissolve them." This description, though by no means so amply characteristic of the class of salts as to serve for an exact definition, is sufficient for our present purpose.

III. " By INFLAMMABLE FOSSILS," the same author observes, " are to be understood all those of mineral origin, whose principal character is inflammability ; a criterion which excludes the diamond and metallic substances, though also susceptible of combustion."

IV. METALLIC SUBSTANCES are so well characterized by external properties, as not to require any definition.—" Those on which nature has bestowed their proper metallic appearance, or

which are alloyed only with other metals or semi-metals, are called *native* metals.   But those that are distinguished, as they commonly are in mines, by combination with some other unmetallic substances, are said to be mineralized.   The substance that sets them in that state is called a mineralizer, and the compound of **both**, an ore."   Thus, in the most common ore of copper, this metal is found oxidized, and the oxide combined with sulphur. The copper may be said to be mineralized by óxygen and sulphur, and the compound of the three bodies is called an ore of copper.

SECTION II.

Method of examining a Mineral, the Composition of which is unknown.

A MINERAL substance, presented to our examination without any previous knowledge of its composition, should first be referred to one of the above four classes, in order that we may attain a general knowledge of its nature, before proceeding to analyze it minutely.

I. To ascertain whether the unknown mineral contain saline matter, let 100 grains, or any other determinate quantity, in the state of fine powder, be put into a bottle, and shaken up repeatedly with 30 times its weight of water, of the temperature of 120° or 130°.   After having stood an hour or two, pour the contents of the bottle on a filtering paper, previously weighed and placed on a funnel.   When the water has drained off, dry the powder on a filtering paper, in a heat of about 212°:   and, when dry, let the whole be accurately weighed.   If the weight be considerably less than the joint weight of the powder before digestion and the filtering paper, we may infer that some salt has been dissolved, and the decrease of weight will indicate its quantity.

In certain cases it may be advisable to use repeated portions of boiling water, when the salt suspected to be present is difficult of solution.

Should the mineral under examination be proved, by the foregoing experiment, to contain much saline matter, the kind and proportion must next be determined, by rules which will hereafter be laid down.

II. The second class, *viz.* earthy bodies, are distinguished by their insolubility in water, by their freedom from taste, by their uninflammability, and by their specific gravity never reaching 5.

If, therefore, a mineral be insoluble in water, when tried in the foregoing manner ; and if it be not consumed, either wholly or in considerable part, by keeping it, for some time, on a red-hot iron ; we may conclude that it is neither a salt nor an inflammable body.

III. The only remaining class with which it can be confounded are ores of metals, from many of which it may be distinguished merely by poising it in the hand, the ores of metals being always heavier than earths ; or, if a doubt should still remain, it may be weighed hydrostatically. The mode of doing this it may be proper to describe ; but the principle on which the practice is founded, cannot with propriety be explained here. Let the mineral be suspended by a piece of fine hair, silk, or thread from the scale of a balance, and weighed in the air. Suppose it to weigh 250 grains. Let it next (still suspended to the balance) be immersed in a glass of distilled water, of the temperature of 60°. The scale containing the weight will now preponderate. Add, therefore, to the scale from which the mineral hangs, as many grain-weights as are necessary to restore equilibrium. Suppose that 50 grains are necessary, then the specific gravity may be learned by dividing the weight in air by the weight lost in water. Thus, in the foregoing case, $250 \div 50 = 5$; or, a substance which should lose weight in water, according to the above proportion, would be five times heavier than water. It must, therefore, contain some metal, though probably in no great quantity.—Any mineral which, when weighed in the above manner, proves to be 5, 6, 7, or more, times heavier than water, may, therefore, be inferred to contain a metal, and may be referred to the class of ores.

IV. Inflammable substances are distinguished by their burning away, either entirely or in considerable part, on a red-hot iron ; and by their detonating, when mixed with powdered nitre, and thrown into a red-hot crucible. Certain ores of metals, however, which contain a considerable proportion of inflammable matter, answer to this test, but may be distinguishsd from purely inflammable substances by their greater specific gravity.

I shall now proceed to offer a few general rules for the more accurate examination of substances of each of the above classes.

SECTION III.

Examination of Salts.

1. A solution of saline matter, obtained in the foregoing manner (see page 243,) may be slowly evaporated, and left to cool

gradually. When cold, crystals will probably appear, which a chemist, acquainted with the forms of salts, will easily recognize. But, as several different salts may be present in the same solution, and may not crystallize in a sufficiently distinct shape, it may be necessary to have recourse to the evidence of tests.

2. Let the salt, in the first place, be referred to one of the following orders.

(*a*) *Acids, or salts with excess of acid.* These are known by their effect on blue vegetable colours. The particular species of acid may be discovered by the tests described, page 235.

(*b*) *Alkalis.* These are characterized by their effect on vegetable colours, and by the other properties enumerated, vol. i. page 173.

(*c*) *Salts with metallic bases.* Metallic salts afford a very copious precipitate when with a solution of prussiate of potash. To ascertain the species of metal, precipitate the whole by prussiate of potash, calcine the precipitate, and proceed according to the rules which will hereafter be given for separating metals from each other.

(*d*) *Salts with earthy bases.* If a solution of salt, in which prussiate of potash occasions no precipitation, afford a preciptate, on adding pure or carbonated potash, we may infer, that a compound of an acid, with some one of the earths, is present in the solution. Or if, after prussiate of potash has ceased to throw down a sediment, the above-mentioned alkali precipitates a farther portion, we may infer that both earthy and metallic salts are contained in the solution. In the first case, add the alkaline solution, and, when it has ceased to produce any effect, let the sediment subside, decant the supernatant liquor, and wash and dry the precipitate. The earths may be examined, according to the rules that will be given in the following article. In the second case, prussiate of potash must be added, as long as it precipitates any thing, and the liquor must be decanted from the sediment, which is to be washed with distilled water, adding the washings to what has been poured off. The decanted solution must next be mixed with the alkaline one, and the preciptated earths reserved for experiment. By this last process, earths and metals may be separated from each other.

(*e*) *Neutral salts with alkaline bases.* These salts are not precipitated either by prussiate or carbonate of potash. It may happen, however, that salts of this class may be contained in a solution, along with metallic or earthy ones. In this case the analysis

becomes difficult; because the alkali, which is added to precipitate the two last, renders it difficult to ascertain whether the neutral salts are owing to this addition, or were originally present. I am not aware of any method of obviating this difficulty, except the following : Let the metals be precipitated by prussiate of ammonia, and the earths by carbonate of ammonia, in a temperature of 180° or upwards, in order to ensure the decomposition of magnesian salts, which this carbonate does not effect in the cold. Separate the liquor by filtration, and boil it to dryness. Then expose the dry mass to such a heat as is sufficient to expel the ammoniacal salts.* Those with bases of fixed alkali will remain unvolatilized. By this process, indeed, it will be impossible to ascertain whether ammoniacal salts were originally present ; but this may be learned by adding to the salt under examination, before its solution in water, some pure potash, which, if ammonia be contained in the salt, will produce the peculiar smell of that alkali. The vegetable and mineral alkalis may be distinguished by adding to the solution a little tartarous acid, which precipitates the former but not the latter ; or by muriate of platina, which acts only on the vegetable alkali.

Having ascertained the basis of the salt, the acid will easily be discriminated. Muriated barytes will indicate sulphuric acid ; nitrate of silver the muriatic ; and salts, containing nitric acid, may be known by a detonation ensuing on projecting them, mixed with powdered charcoal, into a red-hot crucible.

SECTION IV.

Examination of Earths and Stones.

WHEN a mineral, the composition of which we are desirous to discover, resists the action of water, and possesses characters that rank it among earthy bodies, the next object of enquiry is the nature of the earths that enter into its composition ; in other words, how many of the simple earths, and which of them it may contain.—Of these earths (viz. silex, alumine, magnesia, lime, strontites, barytes, zircon, glucine, and yttria,) one or more may be expected in the composition of a mineral, beside a small proportion of metals, to which the colour of the stone is owing. In

* This application of heat will drive off, also, any excess of the ammoniacal carbonate, which might have retained in solution either yttria, glucine, or zircon. The alkaline salts may be separated from these earths, by boiling the mixture in water, filtering, and evaporating.

general, however, it is not usual to find more than four of the sim-
ple earths in one mineral. The newly discovered earths, zircon,
glucine, and yttria, occur very rarely.

A stone, which is intended for chemical examination, should be
finely powdered, and care should be taken that the mortar is of
harder materials than the stone, otherwise it will be liable to ab-
rasion, and uncertainty will be occasioned in the result of the pro-
cess. A longer or shorter time is required, according to the tex-
ture of the stone. Of the harder gems, 100 grains require two or
three hours trituration. For soft stones, a mortar of Wedgwood's
ware is sufficient; but, for very hard minerals, one of agate, or
hard steel, is required; and the stone should be weighed both be-
fore and after pulverization, that the addition, if any, may be as-
certained and allowed for. Gems, and stones of equal hardness,
gain generally from 10 to 13 *per cent*. When a stone is extreme-
ly difficult to be reduced to powder, it may sometimes be neces-
sary to make it red-hot, and while in this state to plunge it into
cold water. By this process it becomes brittle, and is afterwards
easily pulverized. But this treatment is not always effectual; for
Klaproth found the hardness of corundum not at all diminished
by igniting it, and quenching in cold water.

The chemical agents, employed in the analysis of stones, should
be of the greatest possible purity. To obtain them in this state,
directions have been given in the former part of this work.

In treating of the analysis of stones, it may be proper to divide
them, 1st, into such as are soluble, either wholly or in part, and with
effervescence, in nitric or muriatic acids, diluted with five or six
parts of water; and, 2dly, into such as do not dissolve in these a-
cids.

1. *Earths or stones, soluble with effervescence, in diluted nitric
or sulphuric acids.**

(A) If it be found, on trial, that the mineral under examination
effervesces with either of these acids, let a given weight, finely
powdered, be digested with one of them diluted in the above pro-
portion, in a gentle heat, for two or three hours. Ascertain the
loss of weight, in the manner pointed out, page 232, and filter the
solution, reserving the insoluble portion.

(B) The solution, when effected, may contain lime, magnesia,
alumine, barytes, or strontites. To ascertain the presence of the
two last, dilute an aliquot part of the solution with 20 times its
bulk of water, and add a little sulphuric acid, or, in preference,

* The sulphuric acid is chiefly eligible for stones of the magnesian genus.

solution of sulphate of soda.   Should a white precipitate fall down, we may infer the presence of barytes, of strontites, or of both.

(C) To ascertain which of these earths (*viz.* barytes or stron-tites) is present, or, if both are contained in the solution, to sepa-rate them from each other, add sulphate of soda till the precipi-tate ceases ; decant the supernatant liquid ; wash the sediment on a filter, and dry it.—Then digest it, with four times its weight of pure carbonate of potash, and a sufficient quantity of water, in a gentle heat, during two or three hours.   A double exchange of principles will ensue, and we shall obtain a carbonate of barytes or strontites, or a mixture of both.   Pour on these, after being well washed, nitric acid, of the specific gravity 1.4, diluted with an e-qual weight of distilled water.   This will dissolve the strontites, but not the barytes.   To determine whether any strontites has been taken up by the acid, evaporate the solution to dryness, and dissolve the dry mass in alcohol.   This alcoholic solution, if it contain nitrate of strontites, will burn with a deep blood-red flame.

Barytes and strontites may also be separated from each other in the following manner : To a saturated solution of the two earths in an acid, add prussiate of potash, which, if pure, will oc-casion no immediate precipitation ; but, after some time, small and insoluble crystals will form on the surface of the jar.   These are the prussiated barytes, which may be changed into the carbo-nate by a red-heat, continued, with the access of air, till the black colour disappears.   The strontites may be afterward separated from the solution by carbonate of potash.

A third method of separating strontites from barytes is founded on the stronger affinity of barytes, than of the former earth, for a-cids.   Hence if the two earths be present in the same solution, add a solution of pure barytes, till the precipitation ceases.   The barytes will seize the acid, and will throw down the strontites. The strontitic solution, in this case, should have no excess of a-cid, which would prevent the action of the barytic earth.*

(D) The solution (B,) after the addition of sulphate of soda, may contain lime, magnesia, alumine, and some metallic oxides. To separate the oxides, add prussiate of potash, till its effect ceases, and filter the solution, reserving the precipitate for future experiments.

* Klaproth separates barytes from strontites by evaporating the mixed solutions of both.   The barytic salt, being less soluble, separates first ; and the strontitic is contained in the last portions.

(E) When lime, magnesia, and alumine, are contained in the same solution, proceed as follows:

(*a*) Precipitate the solution, previously made hot, by carbonate of potash; wash the precipitate well, and dry it. It will consist of carbonate of lime, magnesia, and alumine. (*b*) The alumine may be separated, by digestion with a solution of pure potash, which will dissolve the alumine but not the other earths. (*c*) To this solution of alumine, add diluted muriatic acid, till the precipitate ceases; decant the supernatant liquor; wash the precipitate well with distilled water, and dry it. Then expose it to a low red-heat, in a crucible, and weigh it, which will give the proportion of alumine.

(F) Magnesia and lime may be separated by the following process: Evaporate the solution, in nitric or muriatic acid, to dryness. Weigh the dry mass, and pour on it, in a glass evaporating dish,* more than its own weight of strong sulphuric acid. Apply a sand-heat till the acid ceases to rise, and then raise the heat, so as to expel the excess of sulphuric acid. Weigh the dry mass, and digest it in twice its weight of cold distilled water.—This will dissolve the sulphate of magnesia, and will leave the sulphate of lime, which must be put on a filter, washed with a little more water, and dried in a low red-heat. To estimate the quantity of lime, deduct, from the weight of the sulphate, 59 *per cent*. According to Klaproth, (vol. i. page 76, n.) crystallized sulphate of lime contains one third of earth.

If the lime be only in very small proportion to the magnesia, the two sulphates may be separated by evaporation, that of lime crystallizing first.

From Klaproth's experiments, 100 parts of sulphuric acid, specific gravity 1850, when saturated with lime, give 160 of sulphate. To saturate 100 parts of this acid, 55 parts of pure lime are required, or 100 of carbonate of lime.

The magnesia is next to be precipitated from the sulphate by the carbonate of potash, in a heat approaching 212°; and the precipitate, after being well washed, must be dried, and calcined for an hour. Its weight, after calcination, will give the quantity of magnesia contained in the stone.

(G) If magnesia and alumine only be contained in a solution (the absence of lime being indicated by the non-appearance of a

* The bottom of a broken Florence flask answers this purpose extremely well, and bears, without breaking, the heat necessary to expel the sulphuric acid.

precipitate, on adding oxalate of ammonia,) the two earths may be separated by adding, to the cold solution, the carbonate of ammonia. This will separate the alumine, which may be collected, washed, and dried. To ascertain that a complete separation of the two earths has been accomplished, the process may be followed, recommended by Klaproth, vol. i. page 418. The magnesia, remaining in solution, may be precipitated by carbonate of potash ; heat being applied, to expel the excess of carbonic acid.

Magnesia and alumine may, also, be separated by succinate of soda, which precipitates the latter earth only. (See sect. 1, xvii. of the chapter on Mineral Waters.)

When the solution of magnesia, of alumine, or of both, contains a small proportion of iron, this may be separated from either or both of the earths by evaporating to dryness, calcining the residue, during one hour, in a low red-heat, and dissolving again in dilute nitric acid, which does not take up iron when thus oxidized.

(H) The insoluble residue (A) may contain alumine, silex, and oxides of metals, so highly charged with oxygen as to resist the action of nitric and muriatic acids.

(a) Add concentrated sulphuric acid, with a small quantity of potash, and evaporate the mixture to dryness, in the vessel described in the note, page 249. On the dry mass pour a fresh portion of the acid ; boil again to dryness, and let this be done, repeatedly, three or four times. By this operation, the alumine will be converted into a sulphate of alumine and potash, which will be easily soluble in warm water ; and, from the solution, crystals of alum will shoot on evaporation.* Let the sulphate of alumine be washed off, and the insoluble part be collected and dried. The alumine may be precipitated by carbonate of potash ; washed, dried, and ignited ; and its weight ascertained.

During the evaporation of a solution of alumine, which has been separated from silex, portions of the latter earth continue to fall, even to the last. (See Klaproth, vol. i. pages 66 and 75.) These must be collected, and washed with warm water ; the collected earth added to the portion (b,) and the washings to the solution (a.)

Alumine may be separated from oxide of iron by a solution of pure potash.

From whatever acid alumine is precipitated by fixed alkali, it is apt to retain a small portion of the precipitant. To ascertain the

* Klaproth procured crystals of alum from one fourth of a grain of alumine. The quantity of alumine he estimates at one tenth the weight of the crystallized alum which is obtained.

true quantity of this earth, it must, therefore, be re-dissolved in acetous acid, again precipitated by solution of pure ammonia, dried, and ignited.

(*b*) The oxides (generally of iron only) may be separated from the silex in the following manner :—Let the insoluble part (*a*) be heated in a crucible with a little wax. This will render the oxides soluble in diluted sulphuric acid, and the silex will be left pure and white. Let it be washed, ignited, and its weight ascertained.

2. *Stones insoluble in diluted nitric and muriatic acids.*

These stones must be reduced to powder, observing the cautions given in page 247.

(I) Let 100 grains, or any other determinate quantity, be mixed with three times their weight of pure and dry potash. Put the whole into a crucible of pure silver, set in one of earthen ware of a larger size, the interstice being filled with sand; and add a little water.* The crucible, covered with a lid, must then be gradually heated ; and, as the materials swell and would boil over, they are to be stirred constantly with a rod or a spatula of silver. When the moisture is dissipated, and the mass has become quite dry, raise the heat as far as can be done without melting the crucible, if of silver, and continue the heat during half an hour, or an hour.

The phenomena that occur during this operation, indicate, in some degree, the nature of the mineral under examination. If the mixture undergo a perfectly liquid fusion, we may presume that the stone contains much siliceous earth ; if it remain pasty and opake, the other earths are to be suspected ; and, lastly, if it have the form of a dry powder, the bulk of which has considerably increased, it is a sign of the predominance of alumine.

If the fused mass have a dark green or brownish colour, the presence of oxide of iron is announced ; a bright green indicates manganese, especially if the colour be imparted to water ; and a yellowish green the oxide of chrome.

(*a*) The disintegration of stones, consisting chiefly of alumine, is not easily effected, however, by means of potash. Mr. Chene-

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* Klaproth effected the disintegration of corundum (which resisted eleven successive fusions with alkali) by adding to the powdered stone, in a crucible, a solution of pure potash, boiling to dryness, and pushing the mixture to fusion. The alkali must be perfectly caustic, and must have been purified by alcohol, as recommended, vol. i. page 173-4. A platina crucible is unfit for this purpose, as it is corroded by pure alkalis.

vix found (Philosophical Transactions, 1802) that minerals of this class are much more completely decomposed by fusion with calcined borax. One part of the mineral to be examined, reduced to very fine powder, and mingled with $2\frac{1}{2}$ or three times its weight of glass of borax (see chap. xvi.) is to be exposed to a strong heat for two hours in a crucible of platina, set in a large earthen one, and surrounded by sand. The crucible and its contents, which adhere very strongly to it, are then to be digested, for some hours with muriatic acid, by which a perfect solution will be accomplished. The whole of the earthy part is then to be precipitated by sub-carbonate of ammonia; and the precipitate, after being well washed, is to be re-dissolved in muriatic acid. By this means, the borax is separated. The analysis is afterwards to be conducted nearly in the manner which will presently be described.

(K) The crucible, being removed from the fire, is to be well cleaned on the outside, and set, with its contents, in a porcelain or glass vessel, filled with hot water, which is to be stirred and renewed, occasionally, till the whole mass is detached. The water dissolves a considerable part of the compound of alumine and silex with potash, and even the whole, if added in sufficient quantity. During cooling, a sediment occasionally forms, in the filtered liquor, of a brownish colour, which is oxide of manganese. See Klaproth, h 345, b.)

(L) To the solution (K,) and the mass that has resisted solution, in the same vessel, add muriatic acid. The first portions of acid will throw down a flocculent sediment, which consists of the earths that were held dissolved by the alkali. Then an effervescence ensues; and a precipitate occurs, which is no sooner formed than it is dissolved. Lastly, the portion that resisted the action of water is taken up, silently if it contain alumine, and with effervescence if it be calcareous earth.

(M) From the phenomena attending the action of muriatic acid, some indications may be derived. If the solution assume a purplish red colour, it is a sign of oxide of manganese; an orange red shows iron; and a gold yellow colour betokens chrome. Freedom from colour proves, that the stone contains no metallic ingredients.

(N) When the solution is complete, it is to be evaporated to dryness in a glass vessel; but, if any thing resist solution, it must be heated, as before (I,) with potash. When the liquor approaches

to dryness, it assumes the form of a jelly, and must then be diligently stirred till quite dry.

(O) (*a*) Let the dry mass be digested, in a gentle heat, with three or four pints, or even more, of distilled water, and filtered. (*b*) Wash what remains on the filter, repeatedly, till the washing ceases to precipitate the nitrate of silver, and add the washings to the filtered liquor. (*c*) Let the residue on the filter be dried and ignited in a crucible. Its weight shows the quantity of silex. If pure, it should be perfectly white, but if it has any colour, an admixture of some metallic oxide is indicated. From this it may be purified by digestion in muriatic acid, and may again be washed, ignited, and weighed.

(P) The solution (O,) which, owing to the addition of the washings, will have considerable bulk, is next to be evaporated, till less than a pint remains ; carbonate of potash must then be added, and the liquor must be heated during a few minutes. Let the precipitate, occasioned by the alkali, subside ; decant the liquor from above it, and wash the sediment, repeatedly, with warm water. Let it then be put on a filter and dried.

(Q) The dried powder may contain alumine, lime, magnesia, barytes, or strontites ; besides metallic oxides, which may be separated from each other by the rules already given.

(R) It may be proper to examine the solution (P) after the addition of carbonate of potash, in order to discover whether any and what acid was contained in the stone.

(*a*) For this purpose, let the excess of alkali be neutralized by muriatic acid, and the liquor filtered.

(*b*) Add, to a little of this liquor, a solution of muriated barytes. Should a copious precipitate ensue, which is insoluble in dilute muriatic acid, the presence of sulphuric acid is detected. And if much barytes, strontites, or lime, has been found in the precipitate (Q,) we may infer the presence of a sulphate of one of these three earths.

(*c*) If, on mixing the liquid (*a*) with the solution of muriated barytes, a precipitate ensues which is soluble, without effervescence, in muriatic acid, the phosphoric acid may be known to be present ; and, if lime be also found, the phosphate of lime is indicated.

(*d*) To a portion of the liquor (*a*) add a solution of muriate of lime till the precipitate, if any, ceases. Collect this precipitate, wash it, dry it, and pour on it a little sulphuric acid. Should acid fumes arise, the fluoric acid may be suspected. To ascertain its

presence decisively, distil a portion of the precipitate with half its weight of sulphuric acid. The fluoric acid will be known by its effects on the retort, and by the properties described, chap. xvii.

(S) The method of separating, from each other, the metallic oxides, usually found as the colouring ingredients of stones, remains to be accomplished.

(*a*) Let the precipitate, by the prussiate of potash (D,) be exposed to a red-heat, by which the prussic acid will be decomposed. The oxides thus obtained, if insoluble in dilute nitric or muriatic acid, will be rendered soluble, by again calcining them with the addition of a little wax or oil.

(*b*) Or the process may be varied by omitting the precipitation by prussiate of potash, and proceeding as directed (E,) page 249.

The oxides will remain mixed with the magnesia and lime, and, after the addition of sulphuric acid, will be held in solution by that acid, along with magnesia only.

In both cases the same method of proceeding may be adopted ; such variation only being necessary as is occasioned by the presence of magnesia in the latter.

(*c*) To the solution (*a* or *b*) containing several metallic oxides dissolved by an acid, add a solution of crystallized carbonate of potash, as long as any precipitation ensues. This will separate the oxides of iron, chrome, and nickel ; but the oxide of manganese and the magnesia, if any be present, will remain dissolved.

If a small quantity of oxide of manganese be suspected in an oxide of iron, it may be detected by mixing the oxide with nitre, and throwing the mixture into a red-hot crucible. Manganese will be indicated by an amethystine red tinge in the solution of this nitre.

(*d*) Magnesia and oxide of manganese may be separated by adding to their solution (*c*) the hydro-sulphuret of potash (see vol. i. page 263,) which will throw down the manganese, but not the magnesia. The precipitated manganese must be calcined with the access of air and weighed. The magnesia may afterward be separated by solution of pure potash ; and, when precipitated, must be washed, dried, and calcined.

(*e*) The oxide of chrome may be separated from those of iron and nickel, by repeatedly boiling the three to dryness, with nitric acid. This will acidify the chrome, and will render it soluble in pure potash, which does not take up the other oxides. From this combination with potash the chromic oxide may be detached by

adding muriatic acid and evaporating the liquor till it assumes a green colour. Then, on adding a solution of pure potash, the oxide of chrome will fall down, because the quantity of oxygen, required for its acidification, has been separated by the muriatic acid.

(*f*) The oxides of iron and nickel are next to be dissolved in muriatic acid ; and to the solution pure liquid ammonia is to be added, till there is an evident excess of it. The oxide of iron will be precipitated, and must be dried and weighed. If highly oxidized, it must, before weighing, be calcined with wax, in a crucible. The oxide of nickel remains dissolved by the excess of ammonia, to which it imparts a blue colour. It may be separated by evaporating the solution to dryness and dissolving the salt.*

The analysis of the stone is now completed, and its accuracy may be judged by the correspondence of the weight of the component parts with that of the stone originally submitted to experiment.

It may be proper to observe, that certain stones, which are not soluble in diluted nitric and muriatic acids, may be decomposed by an easier process than that described (A.) Among these are the compounds of barytes, strontites, and lime, with acids, chiefly with the sulphuric, fluoric, and phosphoric. The sulphates of barytes, strontites, and lime ; the fluate of lime ; and the phosphate of lime ; are all found native in the earth, and, except the last, are all insoluble in the above-mentioned acids. They may be known generally by their external characters. The compounds of barytes and strontites have a specific gravity greater than that of other earths, but inferior to that of metallic ores. They have, frequently, a regular or crystallized form, are more or less transparent, have some lustre, and their hardness is such as does not prevent their yielding to the knife. The combinations of lime, with the above-mentioned acids, are distinguished by similar characters, except that they are much less heavy. To the mineralogist the outward form and characters of these stones are sufficient indications of their composition.

Instead of the fusion with alkali, an easier process may be recommended. Let the mineral under examination be reduced to powder, and be digested, in nearly a boiling heat, during one or two hours, with three or four times its weight of carbonate of pot-

* For an example of the separation of nickel from iron, see Klaproth, vol. i. page 422 : where, also, and page 428, is an instance of the testing of nickel for copper.

ash, and a sufficient quantity of distilled water. The acid, united
with the earth, will quit it and pass to the potash, while the car-
bonic acid will leave the alkali and combine with the earth. We
shall obtain, therefore, a compound of the acid of the stone with
potash, which will remain in solution, while the carbonated earths
will form an insoluble precipitate. The solution may be assayed
to discover the nature of the acid, according to the formula (I ;)
and the earths may be separated from each other by the processes
(B,) &c.

(T) In the foregoing rules for analysis I have omitted the mode
of detecting and separating *glucine*, because this earth is of very
rare consequence. When alumine and glucine are present in a
mineral, they may be separated from the precipitate (E. *a*) by pure
potash, which dissolves both these earths. A sufficient quantity
of acid is then to be added to saturate the alkali; and carbonate
of ammonia is to be poured in till a considerable excess of this
carbonate is manifested by the smell. The alumine is thus sepa-
rated, but the glucine, being soluble in the carbonate of ammo-
nia, remains dissolved, and may be precipitated by boiling the so-
lution.

(U) Zircon may be separated from alumine, by boiling the mix-
ed earths with pure soda, which acts only on the latter. (Klaproth,
vol. ii. page 154.) From an acid solution containing both earths,
the alumine is thrown down by a saturated carbonate of potash,
which, when added in excess, re-dissolves the zircon. Glucine
and zircon, or glucine and yttria, may be separated, when mixed
together in solution, by prussiate of potash, which has no action
on glucine, but precipitates the two other earths.

(V) To separate yttria from alumine, precipitate them from a
solution containing both earths, by pure ammonia; boil the precip-
itate in a solution of pure soda, which chiefly takes up alumine;
neutralize the solution with sulphuric acid, and add carbonate of
soda to the solution, brought to the boiling temperature. A pre-
cipitate will ensue, consisting of alumine, with some yttria. To
separate the latter earth, dissolve in muriatic acid, and add an ex-
cess of carbonate of ammonia, which takes up only the yttria. To
ensure, still farther, the purity of the alumine, dissolve the residue
in an excess of sulphuric acid : add a small portion of sulphate of
potash, and crystallize the solution. The crystals of alum, that
are produced, contain one tenth of alumine.

(W) The presence of potash (which has lately been discover-
ed in some stones) may be detected by boiling the powdered min-

eral, repeatedly to dryness, with strong sulphuric acid. Wash the dry mass with water, add a little excess of acid, and evaporate the solution to a smaller bulk. If crystals of alum should appear, it is a decisive proof of potash, because this salt can never be obtained, in a crystallized form, without the addition of the vegetable alkali.

But, since a mineral may contain potash, and little or no alumine, in which case no crystals of alum will appear, it may be necessary, in the latter case, to add a little alumine along with the sulphuric acid. Or the stone may be so hard as to resist the action of sulphuric acid; and it will then be necessary to fuse it (in the manner directed (I) with soda, which has also a solvent power over alumine and silex. The fused mass is to be dissolved in water, and super-saturated with sulphuric acid. Evaporate to dryness, re-dissolve in water; and filter, to separate the silex. Evaporate the solution, which will first afford crystals of sulphate of soda, and afterwards of sulphate of potash, should the latter alkali be contained in the mineral.

Klaproth first discovered potash in leucite, on summing up the results of its analysis, which gave a considerable loss of weight. By boiling the stone with diluted muriatic acid, and evaporation, he obtained crystals of muriate of potash. Another proof of the presence of potash was, that, when sulphuric acid was boiled with it, the solution gave crystals of alum, to which potash is essential. He also boiled the stone with muriatic acid, and, after dissolving the muriate of alumine by alcohol, muriate of potash remained. The volcanic leucite contained less potash than other kinds. The same alkali he also detected, afterwards, in lepidolite.

The potash, contained in sulphate of alumine, may be separated from the earth by adding a solution of pure barytes as long as any precipitation is produced. The alumine and sulphate of barytes will fall down together, and the potash will remain in solution. Its presence may be known by the tests, enumerated in the first chapter of part ii. (sect. 2.)

X. Soda may be detected in a mineral by the following experiments :—Let the powdered stone be treated with sulphuric acid, as in (U ;) wash off the solution, and add pure ammonia till the precipitation ceases; then filter, evaporate the solution to dryness, and raise the heat so as to expel the sulphate of ammonia. The sulphate of soda will remain, and may be known by the characters,

Soda was first found, by Klaproth, in chryolite, in the large pro-

portion of 36 *per cent*. This analysis was confirmed by Vauquelin, whose mode of separating it happens to be the one I now recommend. Both the fixed alkalis have since been frequently discovered in native minerals ; *viz.* soda in basalt (Klaproth, ii. 195 ;) in pitch-stone (207 ;) and in kling-stone, amounting to 8 *per cent*. (182.) The same skilful analyst has found potash in Hungarian pearl-stone (26 ;) and, accompanied by soda, in pumice (20.)

A new method has been proposed by Mr. Davy (Philosophical Transactions, 1805 ; or Nicholson's Journal, xiii. 86,) for analyzing stones, containing either of the fixed alkalis; *viz.* by means of the boracic acid. The process is sufficiently simple. One hundred grains of the stone to be examined must be fused, during half an hour, at a strong red-heat, with 200 grains of boracic acid. An ounce and half of nitric acid, diluted with seven or eight parts of water, must be digested on the mass, till the whole has been decomposed. The fluid must be evaporated, till its quantity is reduced to an ounce and half, or two ounces.

If the stone contain silex, this earth will be separated in the process on solution and evaporation. It must be collected of a filter, and washed well with water, till the boracic acid, and all the saline matter are separated. The fluid, and all that has passed through the filter, must be evaporated to about half a pint ; then saturated with carbonate of ammonia ; and boiled with an excess of that salt, till all the materials that it contains, capable of being precipitated, have fallen to the bottom of the vessel. The solution must then be passed through a filter, which retains the earths and metallic oxides. It must then be mixed with nitric acid, till the boracic acid appears free. The fluid must next be evaporated to dryness ; when by exposure to a heat of 450° Fahrenheit, the nitrate of ammonia will be decomposed, and the nitrate of potash or soda will remain in the vessel.

The remaining earths and metallic oxides are separated from each other by common processes ; *viz.* alumine by solution of potash ; lime by sulphuric acid ; oxide of iron by succinate of ammonia ; oxide of manganese by hydro-sulphuret of potash ; and magnesia by pure soda.

2. *Table of Substances which may be expected in Earths and Stones, and references to the means of separating them from each other.*

Acid, fluoric, R. *d.*

   phosphoric, R. *c.*

   sulphuric, R. *b.*

Alumine from lime and magnesia, E.

    its quantity, E. *c.*

    from magnesia, G.

     silex, H. *a.*

     metallic oxides, H. *a.*

     glucine, T.

Barytes and *Strontites* from other earths, B.

     from strontites, C.

Chrome from manganese, &c. S. *c.*

     iron and nickel, S. *e.*

Earths from oxides, D.

Glucine from alumine, T.

Iron from manganese, S. *c.*

   nickel, S. *f.*

Lime from magnesia, F.

    alumine, E. *b.*

   its quantity, F.

Magnesia from lime, F.

     alumine, G.

     manganese, S. *d.*

    its quantity, F.

Manganese, indications of, M.

     from iron, chrome, and nickel, S. *c.*

      magnesia, S. *d.*

Nickel from manganese, S. *e.*

Nickel from iron, S. *f.*

Oxides, metallic, from earths, D.

Potash from earths and oxides, W.

Silex from alumine, H. *a.*

    earths in general, O. *c.*

    oxides, H. *b.*

Soda from earths and oxides, X.

Strontites, see *Barytes.*

Yttria from alumine, &c. V.

Zircon from alumine, &c. U.

SECTION V.

Analysis of Inflammable Fossils.

THE exact analysis of inflammable fossils is seldom necessary in directing the most beneficial application of them. It may be proper, however, to offer a few general rules for judging of their purity.

I.—*Sulphur.*

Sulphur should be entirely volatilized by distillation in a glass retort. If any thing remain fixed, it must be considered as an impurity, and may be examined by the preceeding rules.

Sulphur, also, should be totally dissolved by boiling with solution of pure potash, and may be separated from its impurities by this alkali.

Impure sulphur, consumed by burning in a small crucible, leaves a residue of oxide of iron and silex.

II.—*Coals.*

1. The proportion of bituminous matter in coal may be learnt by distillation, in an earthen retort, and collecting their product.

2. The proportion of earthy or metallic ingredients may be found, by burning the coal with access of air, on a red-hot iron. What remains unconsumed must be considered as an impurity, and may be analyzed by the foregoing rules.

3. The proportion of carbon may be ascertained by observing the quantity of nitrate of potash which a given weight of the coal is capable of decomposing. For this purpose, let 500 grains, or more, of perfectly pure nitre be melted in a crucible, and, when red-hot, let the coal to be examined, reduced to a coarse powder, be projected on the nitre, by small portions at once, not exceeding one or two grains. Immediately, when the flame, occasioned by one projection, has ceased, let another be made, and so on till the effect ceases. The proportion of carbon in the coal is directly proportionate to the quantity required to alkalize the nitre. Thus, since 12,709 of carbon are required to alkalize 100 of nitre, it will be easy to deduce the quantity of carbon, in a given weight of coal, from the quantity of nitre which it is capable of decomposing. This method, however, is liable to several objections, which its inventor, Mr. Kirwan, seems fully aware of. (See his Elements of Mineralogy, vol. ii. page 514.)

Plumbago, or *black-lead,* is another inflammable substance,

which it may sometimes be highly useful to be able to identify, and to judge of its purity.—When projected on red-hot nitre, it should detonate ; and, on dissolving the decomposed nitre, an oxide of iron should remain, amounting to one tenth the weight of the plumbago. Any mineral, therefore, that answers to these characters, and leaves a shining trace on paper, like that of the black-lead pencils, is plumbago.

SECTION VI.

Analysis of Metallic Ores.

THE class of metals comprehends so great a number of individuals, that it is almost impossible to offer a comprehensive formula for the analysis of ores. Ores of the same metal, also, as the mineralizing ingredients vary, require very different treatment. Yet some general directions are absolutely necessary, to enable the naturalist to judge of the composition of bodies of this class.

The ores of metals may be analyzed in two modes, in the humid and the dry way. The first is effected with the aid of acids and of other liquid agents, and may often be accomplished by persons who are prevented by the want of furnaces, and other necessary apparatus, from attempting the second. If sulphur, however, be present in an ore, which may be generally known by its external characters, as described by mineralogical writers, it impedes the action of acids ; and should be separated, either by roasting the ore on a muffle, or by projecting it, mixed with twice or thrice its weight of nitre, into a red-hot crucible, washing off the alkali afterwards by hot water.

It is hardly possible to employ a solvent, capable of taking up all the metals. Thus, the nitric acid does not act on gold or platina ; and the nitro-muriatic, which dissolves these metals, has no solvent action on silver. It will be necessary, therefore, to vary the solvent according to the nature of the ore under examination.

1. *For ores of gold and platina,* the nitro-muriatic acid is the most proper solvent. A given weight of the ore may be digested with this acid, as long as it extracts any thing. The solution may be evaporated to dryness, in order to expel the excess of acid, and dissolved in water. The addition of a solution of muriate of tin will show the presence of gold by a purple precipitate ; and platina will be indicated by a precipitate, on adding a solution of muriate of ammonia. When gold and platina are both contained in the same solution, they may be separated from each other by

the last-mentioned solution, which throws down the platina but not the gold. In this way platina may be detached, also, from other metals.

When gold is contained in a solution, along with several other metals, it may be separated from most of them by adding a dilute solution of sulphate of iron. The only metals, which this salt precipitates, are gold, palladium, silver, and mercury.

2. For extracting *silver* from its ores, the nitric acid is the most proper solvent. Nitric acid, however, does not act on horn-silver ore, which must be decomposed by carbonate of soda. The silver may be precipitated from nitric acid by muriate of soda (common salt.) Every 100 parts of the precipitate contains 75 of silver. But, as lead may be present in the solution, and this metal is also precipitated by muriate of soda, it may be proper to immerse in the solution (which should not have any excess of acid) a polished plate of copper. This will precipitate the silver, if present, in a metallic form. The muriate of silver is also soluble in liquid ammonia, which that of lead is not. For examples of the analysis of silver ores, the reader may consult Klaproth, vol. i. page 554, &c.

3. *Copper ores* may be analyzed by boiling them with five times their weight of concentrated sulphuric acid, till a dry mass is obtained, from which water will extract the sulphate of copper. This salt is to be decomposed by a polished plate of iron, immersed in a dilute solution of it. The copper will be precipitated in a metallic state, and may be scraped off and weighed.

If silver be suspected along with copper, nitrous acid must be employed as the solvent; and a plate of polished copper will detect the silver.

The reader, who engages in the analysis of copper ores, will derive much advantage from the examples to be found in Klaproth's Essays, vol. i. pages 54, 541, &c.; and also from Mr. Chenevix's paper on the analysis of arseniates of copper and iron, Philosophical Transactions, 1801; Nicholson's Journal, 8vo. vol. i.; or Philosophical Magazine.

4. *Iron ores* may be dissolved in dilute muriatic acid, or, if the metal be too highly oxidized to be dissolved by this acid, they must be previously mixed with one eighth of their weight of powdered charcoal, and calcined in a crucible for one hour. The iron is thus rendered soluble.

The solution must then be diluted with 10 or 12 times its quantity of water, previously well boiled, to expel the air, and must be preserved in a well-stopped glass bottle for six or eight days.

The phosphate of iron will, within that time, be precipitated, if any be present, and the liquor must be decanted off.

The solution may contain the oxides of iron, manganese, and zinc. It may be precipitated by carbonate of soda, which will separate them all. The oxide of zinc will be taken up by a solution of pure ammonia ; distilled vniegar will take up the manganese, and will leave the oxide of iron. From the weight of this, after ignition, during a quarter of an hour, 28 *per cent.* may be deducted. The remainder shows the quantity of iron.

5. *Tin ores.* To that most accomplished analyst, Klaproth, we owe the discovery of a simple and effectual mode of analyzing tin ores in the humid way.

Boil 100 grains, in a silver vessel, with a solution of 600 grains of pure potash. Evaporate to dryness, and then ignite, moderately, for half an hour. Add boiling water, and, if any portion remain undissolved, let it undergo a similar treatment.

Saturate the alkaline solution with muriatic acid, which will throw down an oxide of tin. Let this be re-dissolved by an excess of muriatic acid ; again precipitated by carbonate of soda ; and, being dried and weighed, let it, after lixiviation, be once more dissolved in muriatic acid. The insoluble part consists of silex. Into the colourless solution, diluted with two or three parts of water, put a stick of zinc, round which the reduced tin will collect. Scrape off the deposite, wash, dry, and fuse it under a cover of tallow in a capsule placed on charcoal. A button of pure metallic tin will remain at the bottom, the weight of which, deducted from that of the ore, indicates the proportion of oxygen.

The presence of tin in an ore is indicated by a purple precipitate, on mixing its solution in muriatic acid with one of gold in nitro-muriatic acid.

6. *Lead ores* may be analyzed by solution in nitric acid, diluted with an equal weight of water. The sulphur, if any, will remain undissolved. Let the solution be precipitated by carbonate of soda. If any silver be present, it will be taken up by pure liquid ammonia. Wash off the excess of ammonia by distilled water ; and add concentrated sulphuric acid, applying heat, so that the muriatic acid may be wholly expelled. Weigh the sulphate of lead, and, after deducting 70 *per cent.* the remainder shows the quantity of lead.

Muriate of lead may also be separated from muriate of silver by its greater solubility in warm water. From the solution, iron

may be separated by prussiate of potash, and the solution decomposed by sulphuric acid.

7. *Mercury* may be detected in ores that are supposed to contain it, by distillation in an earthen retort with half their weight of iron filings or lime. The mercury, if any be present, will rise and be condensed in the receiver.

8. *Ores of zinc* may be digested with the nitric acid, and the part that is dissolved boiled to dryness, again dissolved in the acid, and again evaporated. By this means the iron, if any be present, will be rendered insoluble in dilute nitric acid, which will take up the oxide of zinc. To this solution add pure liquid ammonia, in excess, which will separate the lead and iron, if any should have been dissolved ; and the excess of alkali will retain the oxide of zinc. This may be separated by the addition of an acid, or by the evaporation of the solvent.

9. *Antimonial ores.* Dissolve a given weight, in three or four parts of muriatic and one of nitric acid. This will take up the antimony, and leave the sulphur, if any. On dilution with water, the oxide of antimony is precipitated, and the iron and mercury remain dissolved. Lead may be detected by sulphuric acid. (See Klaproth on the Analysis of Antimoniated Silver Ore, vol. i. page 560.)

10. *Ores of arsenic* may be digested with nitro-muriatic acid, composed of one part nitric, and one and a half or two of muriatic acid. Evaporate the solution to one fourth, and add water, which will precipitate the arsenic. The iron may afterwards be separated by ammonia. (See Chenevix, Philosophical Transactions, 1801, page 215.)

11. *Ores of bismuth* are also assayed by digestion in nitric acid moderately diluted. The addition of water precipitates the oxide, and, if not wholly separated at first, evaporates the solution ; after which, a farther addition of water will precipitate the remainder. (See Analysis of an Ore of Bismuth and Silver, in Klaproth, vol. i. page 554 ; Mode of detecting a small Quantity of Silver in Bismuth, ditto, page 220, c.

12. *Ores of cobalt* may be dissolved in nitro-muriatic acid. Then add carbonate of potash, which at first separates iron and arsenic. Filter, and add a farther quantity of the carbonate, when a greyish red precipitate will fall down, which is oxide of cobalt. The iron and arsenic may be separated by heat, which volatilizes the arsenic. Cobalt is also ascertained, if the solution of an ore in muriatic acid give a sympathetic ink. (See chap. xix. sect. 18.

—An example of the analysis of an ore of cobalt may be seen in Klaproth, vol. i. page 564; and of sulphate of cobalt, page 579.)

13. *Ores of nickel.* Dissolve them in nitric acid, and add to the solution pure ammonia, in such proportion that the alkali may be considerably in excess. This will precipitate other metals, and will retain the oxide of nickel in solution, which may be obtained by evaporation to dryness, and heating the dry mass till the nitrate of ammonia has sublimed.

14. *Ores of manganese.* The earths, and several of the metals, contained in these ores, may first be separated by diluted nitric acid, which does not act on highly oxidized manganese. The ore may afterward be digested with strong muriatic acid, which will take up the oxide of manganese. Oxygenized muriatic acid will arise, if a gentle heat be applied, and may be known by its peculiar smell, and by its discharging the colour of wet litmus paper exposed to the fumes. From muriatic acid the manganese is precipitated by carbonate of soda, in the form of a white oxide, which becomes black when heated in a crucible. Ores, suspected to contain manganese, may also be distilled *per se*, or with sulphuric acid, when oxygen gas will be obtained. Oxide of manganese may be separated from oxide of iron by solution of pure potash, which takes up the former but not the latter. (See the analysis of an ore of manganese, *viâ humidâ*, in Klaproth, vol. i. page 510; and of a cobaltic ore of manganese, page 569.)

Ores of manganese may also be distinguished by the colour they impart to borax, when exposed together to the blow-pipe. (See chap. xviii. sect. 18.)

15. *Ores of uranium.* These may be dissolved in dilute nitric acid, which takes up the uranitic oxide, and leaves that of iron; or in dilute sulphuric acid, which makes the same election; or, if any iron has got into the solution, it may be precipitated by zinc. Then add caustic potash, which throws down the oxide of zinc and uranium. The former may be separated by digestion in pure ammonia, which leaves, undissolved, the oxide of uranium. This, when dissolved by dilute sulphuric acid, affords, on evaporation, crystals of a lemon yellow colour.

If copper be present, it will be dissolved, along with the zinc, by the ammonia. If lead, it will form, with sulphuric acid, a salt much less soluble than the sulphate of uranium, and which, on evaporation, will therefore separate first.

16. *Ores of tungsten.* For these the most proper treatment seems to be digestion in nitro-muriatic acid, which takes up the

earths and other metals. The tungsten remains in the form of a yellow oxide, distinguishable, by its becoming white on the addition of liquid ammonia, from the oxide of uranium. To reduce this oxide to tungsten, mix it with an equal weight of dried blood, heat the mixture to redness, press it into another crucible, which should be nearly full, and apply a violent heat for an hour at least.

17. *Ores of molybdena.* Repeated distillation to dryness, with nitric acid, converts the oxide into an acid, which is insoluble in nitric acid, and may be thus separated from other metals, except iron, from which it may be dissolved by sulphuric or muriatic acids. The solution in sulphuric acid is blue, when cold, but colourless, when heated. That in muriatic acid is only blue, when the acid is heated and concentrated. (See Hatchett's Analysis of the Carinthian Molybdate of Lead, Philosophical Transactions, 1796; and Klaproth, vol. i. pages 534, 538.)

Respecting the ores of the remaining metals, sufficient information has been already given for the purposes of the general student, in part i. chap. xviii. of this work ; and they are of such rare occurrence, that it is unnecessary to describe them more in detail. It may be proper, however, to state where the best examples of the analysis of each may be found.

18. *Ores of titanium.* Consult Gregor, in *Journ. de Physique,* xxxix. 72, 152 ; Klaproth, i. 496 ; and Chenevix, Nicholson's Journal, v. 132.

19. *Ores of tellurium.* See Klaproth, ii. 1.

20. *Ores of tantalium.* *Ann. de Chim.* xliii. 276.

21. *Ores of chromium.* Vauquelin, *Ann. de Chim.* xxv.

22. *Ores of columbium.* Hatchett, Phil. Trans. 1802.

23. *Ores of palladium and rhodium.* Wollaston, Phil. Trans. 1805.

24. *Ores of iridium and osmium.* Tennant, Phil. Trans. 1804.

25. *Ores of cerium.* Hisenger and Berzelius, and Vauquelin, Nicholson's Journal, xii.

SECTION VII.

Analysis of Ores in the dry Way.

To analyze ores in the dry way, a method which affords the most satisfactory evidence of their composition, and should always precede the working of large and extensive strata, a more complicated apparatus is required.—An assaying furnace, with muffles, crucibles, &c. are absolutely necessary. These have al-

ready been enumerated in the chapter on Apparatus, and will be again described in the Explanation of the Plates.

The reduction of an ore requires, frequently, previously roasting to expel the sulphur and other volatile ingredients : or this may be effected, by mixing the powdered ore with nitre, and projecting the mixture into a crucible. The sulphate of potash, thus formed, may be washed off, and the oxide must be reserved for subsequent experiments.

As many of the metals retain their oxygen so forcibly, that the application of heat is incapable of expelling it, the addition of inflammable matter becomes expedient. And to enable the reduced particles of metal to agglutinate and form a collected mass, instead of scattered grains, which would otherwise happen, some fusible ingredient must be added, through which, when in fusion, the reduced metal may descend, and be collected at the bottom of the crucible. Substances that answer both these purposes are called *fluxes*. The alkaline and earthy part of fluxes serve also another end, *viz.* that of combining with any acid which may be attached to a metal, and which would prevent its reduction if not separated.

The ores of different metals, and different ores of the same metal, require different fluxes. To offer rules, however, for each individual case, would occupy too much room in this work : I shall, therefore, only state a few of those fluxes that are most generally applicable.

The *black flux* is formed, by setting fire to a mixture of one part of nitrate of potash, and two of acidulous tartrite of potash ; which affords an intimate mixture of sub-carbonate of potash, with a fine light coal.   *White flux* is obtained by projecting into a red-hot crucible equal parts of the same salts.   Two parts of muriate of soda, previously dried in a crucible, one part of dry and powdered lime, one part of fluate of lime, and half a part of charcoal ; or 400 parts of calcined borax, 40 of lime, and 50 of charcoal ; or, two parts of pounded and finely sifted glass, one of borax, and half a part of charcoal, are all well adapted to the purpose of fluxes. The ore, after being roasted, if necessary, is to be well mixed with three or four times its weight of the flux, and put into a crucible, with a little powdered charcoal over the surface. A cover must be luted on, and the crucible exposed to the necessary heat in a wind-furnace.   Ores of iron, as being difficultly reduced, require a very intense fire.   Those of silver and lead are metallized by a

lower heat.   The metal is found at the bottom of the crucible, in the form of a round button.

The volatile metals, as mercury, zinc, arsenic, tellurium, and osmium, it is obvious, ought not to be treated in the above manner, and require to be distilled with inflammable matters in an earthen retort.

For minute instructions respecting the analysis of every species of ore, both in the humid and dry ways, I refer to the second volume of Mr. Kirwan's Mineralogy; and, for various excellent examples, to the essays of Vauquelin, in the *Annales de Chimie*; to those of Mr. Hatchett and Mr. Chenevix, in the Philosophical Transactions; of Dr. Kennedy, in Nicholson's Journal; and of Mr. Klaproth, in the work already frequently referred to. It is only, indeed, by an attention to these, and a few other models of chemical skill and accuracy, conjoined with the practical imitation of them, that facility, or certainty, in the art of analyzing minerals can be acquired: and though general rules are, in this instance, of considerable utility, it is impossible to frame any that can be adapted to the infinite variety which nature presents in the productions of the mineral kingdom.

PART III.

APPLICATION OF CHEMICAL TESTS AND RE-AGENTS TO VARI-OUS USEFUL PURPOSES.

CHAPTER I.

METHOD OF DETECTING POISONS.

W HEN sudden death is suspected to have been occasioned by the administration of poison, either wilfully or by accident, the testimony of the physician is occasionally required to confirm or invalidate this suspicion. He may also be sometimes called upon to ascertain the cause of the noxious effects arising from the presence of poisonous substances in articles of diet ; and it may therefore serve an important purpose, to point out concisely the simplest and most practicable modes of obtaining, by experiment, the necessary information.

The only poisons, however, that can be clearly and decisively detected by chemical means, are those of the mineral kingdom. Arsenic, and corrosive sublimate,* are most likely to be exhibited with the view of producing death ; and lead and copper may be introduced undesignedly, in several ways, into our food and drink. The continued and unsuspected operation of the two last may often produce effects less sudden and violent, but not less baneful to health and life, than the more active poisons ; and their operation generally involves, in the pernicious consequences, a greater number of sufferers.

SECTION I.

Method of discovering arsenic.

W HEN the cause of sudden death is believed, from the symptoms preceding it, to be the administration of arsenic, the contents of the stomach must be attentively examined. To effect this, let a ligature be made at each orifice, the stomach removed entirely from the body, and its whole contents washed out into an earthen

* I use the term arsenic, instead of the more proper one, arsenous acid; and corrosive sublimate, for muriate of mercury ; because the former terms are more generally understood.

or glass vessel. The arsenic, on account of its greater specific gravity, will settle to the bottom, and may be obtained separate, after washing off the other substances by repeated affusions of cold water. These washings should not be thrown away till the presence of arsenic has been clearly ascertained. It may be expected at the bottom of the vessel in the form of a white powder, which must be carefully collected, dried on a filter, and submitted to experiment.

(A) Boil a small portion of the powder with a few ounces of distilled water, in a clean Florence flask, and filter the solution.

(B) To this solution add a portion of water, saturated with sulphuretted hydrogen gas. If arsenic be present, a golden yellow sediment will fall down, which will appear sooner, if a few drops of acetic acid be added.

(C) A similar effect is produced by the addition of sulphuret of ammonia, or hydro-sulphuret of potash. (See vol. i. page 263.)

It is necessary, however, to observe that these tests are decomposed not only by all metallic solutions but by the mere addition of any acid. But among these precipitates, Dr. Bostock assures us,* the greatest part are so obviously different as not to afford a probability of being mistaken; the only two, which bear a close resemblance to it, are the precipitate from tartarized antimony, and that separated by an acid. In the latter, however, the sulphur preserves its peculiar yellow colour, while the arsenic presents a deep shade of orange ; but no obvious circumstance of discrimination can be pointed out between the hydro-sulphurets of arsenic and of antimony. Hence Dr. Bostock concludes that sulphuretted hydrogen and its compounds merit our confidence only as collateral tests. They discover arsenic with great delicacy : sixty grains of water, to which one grain only of liquid sulphuret (hydroguretted sulphuret ?) had been added, was almost instantly rendered completely opake by $\frac{1}{80}$th of a grain of the white oxide of arsenic in solution.

(D) To a little of the solution (A) add a single drop of a weak solution of carbonate of potash, and afterward a few drops of a solution of sulphate of copper. The presence of arsenic will be manifested by a yellowish green precipitate. Or boil a portion of the suspected powder with a dilute solution of pure potash, and with this precipitate the sulphate of copper, when a similar appearance will ensue still more remarkably, if arsenic be present. The colour of this precipitate is perfectly characteristic. It is

* Edinburgh Medical and Surgical Journal, v. 166.

that of the pigment called Scheele's green. (See chap. xviii. sect. 16.) To identify the arsenic with still greater certainty, it may be proper, at the time of making the experiments on a suspected substance, to perform similar ones, as a standard of comparison, on what is actually known to be arsenic. Let the colour, therefore, produced by adding an alkaline solution of the substance under examination, to a solution of sulphate of copper, be compared with that obtained by a similar admixture of a solution of copper with one of real arsenic in alkali.

The proportions, in which the different ingredients are employed, Dr. Bostock has found to have considerable influence on the distinct exhibition of the effect. Those, which he has observed to answer best, were one of arsenic, three of potash (probably the sub-carbonate or common salt of tartar,) and five of sulphate of copper. For instance, a solution of one grain of arsenic, and three grains of potash, in two drachms of water, being mingled with another solution of five grains of sulphate of copper in the same quantity of water, the whole was converted into a beautiful grass green, from which a copious precipitate of the same hue slowly subsided, leaving the supernatant liquor transparent and nearly colourless. The same materials, except with the omission of the arsenic, being employed in the same manner, a delicate sky-blue resulted, so different from the former, as not to admit of the possibility of mistake. In this way $\frac{1}{40}$th of a grain of arsenic, diffused through sixty grains of water, afforded, by the addition of sulphate of copper and potash in proper proportions, a distinct precipitate of Scheele's green. In employing this test, it is necessary to view the fluid by reflected and not by transmitted light, and to make the examination by day-light. To render the effect more apparent, a sheet of white paper may be placed behind the glass in which the mixed fluids are contained.[*]

(E) The sediments, produced by any of the foregoing experiments, may be collected, dried, and laid on red-hot charcoal. A smell of sulphur will first arise, and will be followed by that of garlic.

(F) A new process for detecting arsenic has been proposed by Mr. Hume of London in the Philosophical Magazine for May 1809, vol. xxxiii. The test which he has suggested, is the fused nitrate of silver or lunar caustic, which he employs in the following manner :[†]

[*] Lib. citat. page 170.
[†] London Medical and Physical Journal, xxiii. 448.

Into a clean Florence oil flask, introduce two or three grains of any powder suspected to be arsenic ; add not less than eight ounce-measures of either rain or distilled water ; and heat this gradually over a lamp or a clear coal fire, till the solution begins to boil. Then, while it boils, frequently shake the flask, which may be readily done by wrapping a piece of leather round its neck, or putting a glove upon the hand. To the hot solution, add a grain or two of sub-carbonate of potash or soda, agitating the whole to make the mixture uniform.

In the next place, pour into an ounce phial or a small wine glass about two table spoonfuls of this solution, and present, to the mere surface of the fluid, a stick of dry nitrate of silver or lunar caustic. If there be any arsenic present, a beautiful yellow precipitate will instantly appear, which will proceed from the point of contact of the nitrate with the fluid, and settle towards the bottom of the vessel as a flocculent and copious precipitate. This precipitate, Mr. Hume is confident, cannot be confounded with any other substance, so as to lead to a doubtful opinion.

The nitrate of silver, Mr. Hume finds, also, acts very sensibly upon *arsenate* of potash, and decidedly distinguishes this salt from the above solution of *arsenite* of potash ; the colour of the precipitate, occasioned by the *arsenate*, being much darker and more inclined to brick or red. In both cases, he is of opinion that the test of nitrate of silver is greatly superior to that of sulphate of copper : inasmuch as it produces a much more copious precipitate, when equal quantities are submitted to experiment. The tests he recommends to be employed in their dry state, in preference to that of solution ; and that the piece of salt be held on the surface only. (See note 40, at the end of this vol.)

(G) But the most decisive mode of determining the presence of arsenic, is by reducing it to a metallic state, in which its characters are clear and unequivocal. For this purpose, let a portion of the white sediment, collected from the contents of the stomach, be mixed with three times its weight of black flux (see page 80;) or if this cannot be procured, with two parts of very dry carbonate of potash (the salt of tartar of the shops,) and one of powdered charcoal. Dr. Bostock finds that for this mixture, we may advantageously substitute one composed of half a grain of charcoal, and two drops of oil, to a grain of sediment. Procure a tube eight or nine inches long, and one fourth or one sixth of an inch in diameter, of thin glass, sealed hermetically at one end. Coat the closed end with clay, for about an inch, and let the coating dry. Then

put into the tube the mixture of the powder and its flux, and if any should adhere to the inner surface, let it be wiped off by a feather, so that the inner surface of the upper part of the tube may be quite clean and dry. Stop the end of the tube loosely, with a little paper, and heat the coated end only, on a chaffing-dish of red-hot coals, taking care to avoid breathing the fumes. The arsenic, if present, will rise to the upper part of the tube, on the inner surface of which it will form a thin brilliant coating. Break the tube, and scrape off the reduced metal. Lay a little on a heated iron, when, if it be arsenic, a dense smoke will arise, and a strong smell of garlic will be perceived. The arsenic may be farther identified, by putting a small quantity between two polished plates of copper, surrounding it by powdered charcoal, to prevent its escape, binding these tightly together by iron wire, and exposing them to a low red-heat. If the included substance be asrenic, a white stain will be left on the copper.

(G) It may be proper to observe, that neither the stain on copper, nor the odour of garlic, is produced by the white oxide of arsenic, when heated without the addition of some inflammable ingredient. The absence of arsenic must not therefore be inferred, if no smell should be occasioned by laying the white powder on a heated iron.

Dr. Black ascertained that all the necessary experiments, for the detection of arsenic, may be made on a single grain of the white oxide ; this small quantity having produced, when heated in a tube with its proper flux, as much of the metal as clearly established its presence.

If the quantity of arsenic in the stomach should be so small, which is not very probable, as to occasion death, and yet to remain suspended in the washings, the whole contents, and the water employed to wash them, must be filtered, and the clear liquor assayed for arsenic by the tests (B,) (C,) (D,) and (E.)

SECTION II.

Discovery of Corrosive Sublimate.

CORROSIVE sublimate (the muriate of mercury,) next to arsenic, is the most virulent of the metallic poisons. It may be collected by treating the contents of the stomach in the manner already described ; but as it is more soluble than arsenic, viz. in about 19 times its weight of water, no more water must be employed than is barely sufficient, and the washings must be carefully preserved for examination.

If a powder should be collected, by this operation, which proves, on examination, not to be arsenic, it may be known to be corrosive sublimate by the following characters:

(A) Expose a small quantity of it, without any admixture, to heat in a coagulated glass tube, as directed in the treatment of arsenic. Corrosive sublimate will be ascertained by its rising to the top of the tube, lining the inner surface in the form of a shining white crust.

(B) Dissolve another portion in distilled water; and it may be proper to observe how much of the salt the water is capable of taking up.

(C) To the watery solution add a little lime-water. A precipitate of an orange yellow colour will instantly appear.

(D) To another portion of the solution add a single drop of a dilute solution of sub-carbonate of potash (salt of tartar.) A white precipitate will appear; but, on a still farther addition of alkali, an orange coloured sediment will be formed.

(E) The carbonate of soda has similar effects.

(F) Sulphuretted water throws down a dark coloured sediment, which, when dried and strongly heated, is wholly volatilized, without any odour of garlic.

The only mineral poison of great virulence that has not been mentioned, and which, from its being little known to act as such, it is very improbable we should meet with, is the carbonate of barytes. This, in the country where it is found, is employed as a poison for rats, and there can be no doubt would be equally destructive to human life. It may be discovered by dissolving it in muriatic acid, and by the insolubility of the precipitate which this solution yields on adding sulphuric acid, or sulphate of soda. Barytic salts, if these have been the means of poison, will be contained in the water employed to wash the contents of the stomach, and will be detected, on adding sulphuric acid, by a copious precipitate.

SECTION III.

Method of detecting Copper or Lead.

COPPER and lead sometimes gain admission into articles of food, in consequence of the employment of kitchen utensils of these materials.

I. If COPPER be suspected in any liquor, its presence will be ascertained by adding a solution of pure ammonia, which will strike

a beautiful blue colour. If the solution be very dilute, it may be concentrated by evaporation ; and if the liquor contain a considerable excess of acid, like that used to preserve pickles, as much of the alkali must be added as is more than sufficient to saturate the acid.

II. LEAD is occasionally found, in sufficient quantity to be injurous to health, in water that has been kept in leaden vessels, and sometimes even in pump-water, in consequence of this metal being used in the construction of the pump. Acetate of lead has also been known to be fraudulently added to bad wines, with the view of concealing their defects.

Lead may be discovered by adding, to a portion of the suspected water, about half its bulk of water impregnated with sulphuretted hydrogen gas. If lead be present, it will be manifested by a dark brown, or blackish, tinge. This test is so delicate, that water, condensed by the leaden worm of a still-tub, is sensibly affected by it. It is also detected by a similar effect ensuing on the addition of sulphuret of ammonia, or potash.

The competency of this method, however, to the discovery of very minute quantities of lead, has been lately set aside by the experiments of Dr. Lambe,* the author of a skilful analysis of the springs of Lemington Priors, near Warwick. By new methods of examination, he has detected the presence of lead in several spring-waters, that manifest no change on the addition of the sulphuretted test ; and has found that metal in the precipitate, separated from such waters by the carbonate of potash or of soda. In operating on these waters, Dr. Lambe noticed the following appearances :

(*a*) The test forms sometimes a dark cloud, with the precipitate effected by alkalis, which has been re-dissolved in nitric acid.

(*b*) Though it forms, in other cases, no cloud, the precipitate itself becomes darkened by the sulphuretted test.

(*c*) The test forms a white cloud, treated with the precipitate as in (*a*.) These two appearances may be united.

(*d*) The test neither forms a cloud, nor darkens the precipitate.

(*e*) In the cases (*b*,) (*c*,) (*d*,) heat the precipitate, in contact with an alkaline carbonate, to redness ; dissolve out the carbonate by water ; and treat the precipitate as in (*a*.) The sulphuretted test then forms a dark cloud with the solution of the precipitate.

* See his " Researches into the Properties of Spring Water." 8vo. London. Johnson. 1803.

In these experiments, it is essential that the acid, used to re-dis-
solve the precipitate, shall not be in excess; and if it should so
happen, that excess must be saturated before the test is applied.
It is better to use so little acid, that some of the precipitate may
remain undissolved.

(*f*) Instead of the process (*e*) the precipitate may be exposed
without addition, to a red-heat, and then treated as in (*a.*) In this
case, the test will detect the metallic matter; but with less cer-
tainty than the foregoing one.

The nitric acid, used in these experiments, should be perfectly
pure; and the test should be recently prepared by saturating wa-
ter with sulphuretted hydrogen gas.

Another mode of analysis, employed by Dr. Lambe, consists in
precipitating the lead by muriate of soda; but as muriate of lead
is partly soluble in water, this test cannot be applied to small por-
tions of suspected water. The precipitate must be, therefore,
collected, from two or three gallons, and heated to redness with
twice its weight of carbonate of soda. Dissolve out the soda; add
nitric acid, saturating any superfluity; and then apply the sulphu-
retted test.

The third process, which is the most satisfactory of all, and is
very easy, except for the trouble of collecting a large quantity of
precipitate, is the actual reduction of the metal, and its exhibition
in a separate form. The precipitate may be mixed with its own
weight of alkaline carbonate, and exposed either with or without
the addition of a small proportion of charcoal, to a heat sufficient
to melt the alkali. On breaking the crucible, a small globule of
lead will be found reduced at the bottom. The precipitate from
about fifty gallons of water yielded Dr. Lambe about two grains
of lead.

For discovering the presence of lead in wines, a test invented
by Dr. Hahnemann, and known by the title of Hahnemann's wine-
test, may be employed. This test is prepared by putting togeth-
er, into a small phial, sixteen grains of sulphuret of lime, prepar-
ed in the dry way (by exposing to a red-heat, in a covered cruci-
ble, equal weights of powdered lime and sulphur, accurately mix-
ed,) and 20 grains of acidulous tartrite of potash (cream of tartar.)
The phial is to be filled with water, well corked, and occasionally
shaken for the space of ten minutes. When the powder has sub-
sided, decant the clear liquor, and preserve it, in a well-stopped
bottle, for use. The liquor, when fresh prepared, discovers lead
by a dark coloured precipitate. A farther proof of the presence

of lead in wines is the occurrence of a precipitate on adding a so-
lution of the sulphate of soda.

The quantity of lead which has been detected in sophisticated
wine, may be estimated at forty grains of the metal in every fifty
gallons. (Lambe, page 175.)

When a considerable quantity of acetate of lead has been taken
into the stomach (as sometimes, owing to its sweet taste, happens
to children,) after the exhibition of an active emetic, the hydro-
sulphuret of potash or of ammonia may be given ; or a solution of
the common sulphuret.

In cases of the accidental swallowing of sulphuric acid, which
also sometimes happens to children, M. Fourcroy recommends
the speedy administration of a solution of soap, or a mixture of
carbonate of magnesia or carbonate of lime (common chalk) with
water. *(Système*, vol. i. page 240.)

CHAPTER II.
RULES FOR ASCERTAINING THE PURITY OF CHEMICAL PREPA-
RATIONS, EMPLOYED FOR THE PURPOSES OF MEDICINE, AND
FOR OTHER USES.

I.—*Sulphuric acid,—Acidum Sulphuricum of the London Pharma-
copœia,—Oil of Vitriol.*

THE specific gravity of sulphuric acid should be 1850. It
should remain perfectly transparent when diluted with distilled
water. If a sediment occur, on dilution, it is a proof of the pres-
ence of sulphate of lead or sulphate of lime.

Iron may be detected in sulphuric acid, by saturating a diluted
portion of the diluted acid with pure carbonate of soda, and adding
prussiate of potash, which will manifest the presence of iron by a
prussian blue precipitate ; or it will be discovered by a purplish
or blackish tinge, on the addition of tincture of galls to a similarly
saturated portion. Copper may be discovered, by pouring, into
a similarly saturated solution, pure solution of ammonia ; and lead
may be detected by the sulphuret of ammonia. The latter metal,
however, is generally precipitated, on dilution, in combination
with sulphuric acid.

Sulphate of potash or of soda may be found by saturating the
diluted acid with ammonia, evaporating to dryness, and applying a
pretty strong heat. The sulphate of ammonia will escape, and
that of potash or of soda will remain, and may be distinguished by
its solubility and other characters. (See vol. i. page 248.)

II.—*Nitric and Nitrous Acids,—Acidum Nitricum, P. L.—Aqua Fortis.*

The nitric acid should be perfectly colourless, and as limpid as water. It should be preserved in a dark place, to prevent its conversion into the nitrous kind.

These acids are most likely to be adulterated with sulphuric and muriatic acids. The sulphuric acid may be discovered by adding to a portion of the acid, largely diluted, nitrated or muriated barytes, which will occasion, with sulphuric acid, a white and insoluble precipitate. The muriatic acid may be ascertained by nitrate of silver, which affords a sediment, at first white, but which becomes coloured by exposure to the direct light of the sun. Both these acids, however, may be present at once; and, in this case, it will be necessary to add a solution of nitrate of barytes, as long as any precipitate falls, which will separate the sulphuric acid. Let the sediment subside, decant the clear liquor, and add the nitrate of silver. If a precipitate appear, muriatic acid may be inferred to be present also. Muriatic acid may, also, be detected by adding a solution of sulphate of silver.

These acids should have the specific gravity of 1550.

III.—*Muriatic Acid,—Acidum Muriaticum, P. L.—Spirit of Salt.*

This acid generally contains iron, which may be known by its yellow colour; the pure acid being perfectly colourless. It may also be detected by the same mode as was recommended in examining sulphuric acid.

Sulphuric acid is discoverable by a precipitation, on adding, to a portion of the acid, diluted with five or six parts of pure water, a solution of the muriate of barytes.

The specific gravity of this acid should be at least 1170.

IV.—*Acetic Acid,—Acidum Aceticum,—Radical or concentrated Vinegar.*

This acid is often contaminated by sulphurous and sulphuric acid. The first may be known by drawing a little of the vapour into the lungs, when, if the acid be pure, no unpleasant sensation will be felt; but, if sulphurous acid be contained in the acetic, it will not fail to be discovered in this mode. The sulphuric acid is detected by muriated barytes; copper, by supersaturation with pure ammonia; and lead, by sulphuret of ammonia.

The specific gravity of this acid should be 1060 at least.

V.—*Acetous Acid,*—*Acidum Accticum, P. L.*—*Distilled Vinegar.*

If vinegar be distilled in copper vessels, it can hardly fail being contaminated by that metal; and, if a leaden worm be used for its condensation, some portion of lead will certainly be dissolved. The former metal will appear on adding an excess of solution of pure ammonia; and lead will be detected by the sulphuretted ammonia, or by water saturated with sulphuretted hydrogen. (See the preceding chapter.)

It is not unusual, in order to increase the acid taste of vinegar, to add sulphuric acid. This acid may be immediately discovered by solutions of barytes, which, when vinegar has been thus adulterated, throw down a white precipitate.

VI.—*Boracic Acid,*—*Sedative Salt of Homberg.*

Genuine boracic acid should totally dissolve in five times its weight of boiling alcohol; and the solution, when set on fire, should emit a green flame. The best boracic acid forms small hexangular scaly crystals of a shining silvery white colour. Its specific gravity is 1480.

VII.—*Tartaric Acid.*

This acid often contains sulphuric acid; to discover which, let a portion be dissolved in water, and a solution of acetate of lead be added. A precipitate will appear, which, if the acid be pure, is entirely re-dissolved by a few drops of pure nitric acid, or by a little pure acetic acid. If any portion remain undissolved, sulphuric acid is the cause. Muriate of barytes, also, when the acid is adulterated with sulphuric acid, but not otherwise, gives a precipitate insoluble by an excess of muriatic acid.

VIII.—*Acid of Amber.*

Acid of amber is adulterated, sometimes with sulphuric acid and its combinations; sometimes with tartaric acid; and at others with muriate of ammonia.

Sulphuric acid is detected by solutions of barytes; tartaric acid by carbonate of potash, which forms a difficultly soluble tartrate; and muriate of ammonia by nitrate of silver, which discovers the acid, and by a solution of pure potash, which excites a strong smell of ammonia.

Pure acid of amber is a crystalline white salt of an acid taste, soluble in twenty-four parts of cold or eight of hot water, and is volatilized, when laid on red-hot iron, without leaving any ashes or other residue.

IX.—*Acid of Benzoin,—Acidum Benzoicum, P. L.*

This acid is not very liable to adulteration. The best has a brilliant white colour and a peculiarly grateful smell. It is soluble in a large quantity of boiling water or alcohol, and leaves no residue when placed on a heated iron.

X.—*Sub-carbonate of Potash,—Potassæ Sub-carbonas, P. L.*

The salt of tartar of the shops generally contains sulphate and muriate of potash, and siliceous and calcareous earths. It should dissolve entirely, if pure, in twice its weight of cold water; and any thing that remains undissolved may be regarded as an impurity. Sometimes one fourth of foreign mixtures may thus be detected, the greater part of which is sulphate of potash. To ascertain the nature of the adulteration, dissolve a portion in pure and diluted nitric acid: the siliceous earth only will remain undissolved. Add, to one portion of the solution, nitrate of barytes; this will detect sulphate of potash by a copious precipitate. To another portion add nitrate of silver, which will discover muriatic salts; and, to a third, oxalate or fluate of ammonia, which will detect calcareous earth.

The solution of sub-carbonate of potash (*liquor potassæ sub-carbonatis, P. L.*) may be examined in a similar manner.

XI.—*Solution of pure Potash,—Liquor Potassæ, P. L.*

This may be assayed, for sulphuric and muriatic salts, by saturation with nitric acid, and by the tests recommended in speaking of carbonate of potash. A perfectly pure solution of potash should remain transparent on the addition of barytic water. If a precipitate should ensue, which dissolves with effervescence in dilute muriatic acid, it is owing to the presence of carbonic acid: if the precipitate is not soluble, it indicates sulphuric acid. A redundancy of carbonic acid is also shown by an effervescence, on adding diluted sulphuric acid, and an excess of lime by a white precipitate, on blowing air from the lungs, through the solution, by means of a tobacco-pipe, or a glass tube.

This solution should be of such a strength, as that an exact wine-pint may weigh 18 ounces troy.

XII.—*Sub-carbonate of Soda,—Sodæ Subcarbonas, P. L.*

Carbonate of soda is scarcely ever found free from muriate and sulphate of soda. These may be discovered by adding, to a little

of the carbonate saturated with pure nitric acid, first nitrate of ba-
rytes, to detect sulphuric acid, and afterward nitrate of silver, to
ascertain the presence of muriatic acid. Carbonate of potash
will be shown by a precipitate ensuing on the addition of tartarous
acid to a strong solution of the alkali; for, this acid forms a diffi-
cultly soluble salt with potash, but not with soda.

XIII.—*Solution of Carbonate of Ammonia,—Liquor Ammoniæ Carbonatis, P. L.*

This should have the specific gravity of 1150; should effervesce
on the addition of acids; and should afford a strong coagulum on
adding alcohol.

XIV.—*Carbonate of Ammonia,—Ammoniæ Carbonas, P. L.*

This salt should be entirely volatilized by heat. If any thing
remain, when it is laid on a heated iron, carbonate of potash or of
lime may be suspected; and these impurities are most likely to
be present if the carbonate of ammonia be purchased in the form
of a powder. It should therefore always be bought in solid lumps.
Sulphuric and muriatic salts, lime and iron, may be discovered by
adding to the alkali, saturated with nitric acid, the appropriate tests
already often mentioned.

XV.—*Solution of pure Ammonia in Water,—Liquor Ammoniæ, P. L.—Strong Spirit of Sal Ammoniac.*

The volatile alkali, in its purest state, exists as a gas conden-
sible by water, and its solution in water is the only form under
which it is applicable to useful purposes. This solution should
contain nothing besides the volatile alkali; the alkali should be
perfectly free from carbonic acid, and should be combined with
water in the greatest possible proportion. The presence of other
salts may be discovered by saturating a portion of the solution
with pure nitric acid, and adding the tests for sulphuric and mu-
riatic acids. Carbonic acid is shown by a precipitation on mix-
ing the solution with one of muriate of lime; for this earthy salt
is not precipitated by pure ammonia. The only mode of deter-
mining the strength of the solution is by taking its specific gravi-
ty, which, at 60° of Fahrenheit, should be as 905, or thereabouts,
to 1000.

XVI.—*Spirit of Hartshorn.*

This may be counterfeited by mixing the *aqua ammoniæ puræ*
with the distilled spirit of hartshorn, in order to increase the pun-

gency of its smell, and to enable it to bear an addition of water. The fraud is detected by adding alcohol to the sophisticated spirit; for, if no considerable coagulation ensues, the adulteration is proved. It may also be discovered by the usual effervescence not ensuing with acids. The solution should have the specific gravity of 1500.

XVII.—*Sulphate of Soda,—Sodæ Sulphas, P. L.—Glauber's Salt.*

This salt ought not to contain an excess of either acid or alkali, both of which may be detected by the vegetable infusions, page 222. Nor should it be mixed with earthy or metallic salts; the former of which are detected by carbonic, and the latter by prussiate of potash. Muriate of soda is discovered by adding nitrate of barytes till the precipitate ceases, and afterwards nitrate of silver, or more simply by a solution of sulphate of silver. Sulphate of potash is discovered by its more sparing solubility. The sulphate of soda, however, being itself one of the cheapest salts, there is little risk of its being intentionally sophisticated.

XVIII.—*Sulphate of Potash,—Potassæ Sulphas, P. L.—Vitriolated Tartar.*

The purity of this salt may be ascertained by the same means as that of the former one. The little value of this salt renders it pretty secure from wilful adulteration..

XIX.—*Nitrate of Potash,—Potassæ Nitras, P. L.—Nitre or Salt Petre.*

Nitrate of potash is, with great difficulty, freed entirely from muriate of soda; and a small portion of the latter, except for nice chemical purposes, is an admixture of little importance. To discover muriate of soda, a solution of nitrate of silver must be added as long as any sediment is produced. The precipitate, washed and dried, must be weighed. Every hundred grains will denote about $42\frac{1}{2}$ of muriate of soda.

Sulphate of potash or soda may be discovered by nitrate or muriate of barytes.

XX.—*Muriate of Soda,—Common Salt.*

Common salt is scarcely ever found free from salts with earthy bases, chiefly muriates of magnesia and lime, which are contained in the brine, and adhere to the crystals. The earths may be pre-

cipitated by carbonate of soda, and the precipitated lime and mag-
nesia may be separated from each other by the rules given page
249.

XXI.—*Muriate of Ammonia,—Ammoniæ Murias, P. L.—Sal Am-moniac.*

This salt ought to be entirely volatilized, by a low heat, when
laid on a heated iron. It sometimes contains sulphate of ammo-
nia, however, which, being also volatile, cannot be thus detected.
To ascertain the presence of the latter salt, add the muriate or ni-
trate of barytes, which will indicate the sulphate by a copious and
insoluble precipitate.

XXII.—*Acetate of Potash,—Potassæ Acetas, P. L.*

Genuine acetate of potash is perfectly soluble in four times its
weight of alcohol, and may thus be separated from other salts that
are insoluble in alcohol. The tartrate of potash (soluble tartar) is
the adulteration most likely to be employed. This may be discov-
ered by adding a solution of tartaric acid, which, if the suspected
salt be present, will occasion a copious precipitate. The tar-
trate is also detected by its forming a precipitate with acetate
of lead or muriate of barytes, soluble in acetic or muriatic acid ;
and sulphates by a precipitate with the same agents, insoluble in
acids.

XXIII.—*Neutral Tartrate of Potash,—Potassæ Tartras, P. L.— Soluble Tartar.*

This salt should afford a very copious precipitate on adding tar-
tarous acid. The only salt likely to be mixed with it is sulphate
of soda, which may be detected by a precipitate with muriated ba-
rytes, insoluble in diluted muriatic acid.

XXIV.—*Acidulous Tartrate of Potash.—Potassæ Supertartras, P. L.—Cream of Tartar.*

The only substance with which this salt is likely to be adulterat-
ed is sulphate of potash. To determine whether this be present,
pour, on about half an ounce of the powdered crystals, two or
three ounce-measures of distilled water ; shake the mixture fre-
quently, and let it stand one or two hours. The sulphate of pot-
ash, being more soluble than the tartrate, will be taken up ; and
may be known by the bitter taste of the solution, and by a precipi-
tate, on adding muriate of barytes, which will be insoluble in mu-
riatic acid.

XXV.—*Compound Tartrate of Soda and Potash,—Soda Tartari-
zata, P. L.—Rochelle or Seignette's Salt.*

Sulphate of soda, the only salt with which this may be expect-
ed to be adulterated, is discovered by adding to a solution of Roch-
elle salt the acetate of lead or muriate of barytes.—The former, if
the sulphate be present, affords a precipitate insoluble in acetous
acid, and the latter one insoluble in muriatic acid.

XXVI.—*Sulphate of Magnesia,—Magnesiæ Sulphas, P. L.—Ep-
som Salt.*

This salt is very likely to be adulterated with sulphate of soda,
or Glauber's salt, which may be made to resemble the magnesian
salt in appearance, by stirring it briskly at the moment when it is
about to crystallize. The fraud may be discovered very readily
if the salt consist entirely of the sulphate of soda, because no pre-
cipitation will ensue on adding carbonate of potash. If only a
part of the salt be sulphate of soda, detection is not so easy, but
may still be accomplished. For, since 100 parts of pure sulphate
of magnesia give between 30 and 40 of the dry carbonate, when
completely decomposed by carbonate of potash, if the salt under
examination afford a considerably less proportion, its sophistica-
tion may be fairly inferred : or, to discover the sulphate of soda,
precipitate all the magnesia by pure ammonia, with the aid of heat.
Decant the clear liquor from the precipitate, filter it, and, after
evaporation to dryness, apply such a heat as will volatilize the sul-
phate of ammonia, when that of soda will remain fixed.

Muriate of magnesia or of lime may be detected by the salt be-
coming moist when exposed to the air, and by a precipitation with
nitrated silver, after nitrate of barytes has separated all the sul-
phuric acid and magnesia. Lime is discoverable by oxalic acid.

XXVII.—*Sulphate of Alumine,—Alum.*

Perfectly pure alum should contain neither iron nor copper.
The former is manifested by adding, to a solution of alum, prus-
siate of potash, and the latter by an excess of pure ammonia.

XXVIII.—*Borate of Soda,—Sodæ Boras, P. L.—Borax.*

Borate of soda, if adulterated at all, will probably be so with al-
um or fused muriate of soda. To discover these, borax must be
dissolved in water, and its excess of alkali be saturated with ni-
tric acid. Nitrate of barytes, added to this saturated solution,
will detect the sulphuric salt, and nitrate of silver the muriate of
soda.

XXIX.—*Sulphate of Iron,—Ferri Sulphas, P. L.—Green Vitriol.*

If this salt should contain copper, which is the only admixture likely to be found in it, pure ammonia, added till a precipitation ceases, will afford a blue liquor. Any copper that may chance to be present may be separated, and the salt purified, by immersing, in a solution of it, a clear polished plate of iron.

XXX.—*Glass of Antimony.*

A large quantity of glass of *lead* was lately introduced into the London market, as glass of *antimony*. To discover this criminal imposition, whenever it may be practised, the following distinctive characters of the two substances have lately been described by Mr. Luke Howard.*

Glass of antimony has a rich brown or redish colour, with the usual transparency of coloured glasses. The glass of lead is of a deeper and duller colour against the light; is much less transparent; and even, in some samples, quite opake.

The specific gravity of the true never exceeds 4.95; that of the spurious or lead glass is 6.95; or, in round numbers, their comparative weights are as 5 to 7.

Let twenty grains be rubbed fine in a glass mortar, adding half an ounce of good muriatic acid. The true dissolves with an hepatic smell; the solution is turbid, but has no sediment. The spurious turns the acid yellow, giving out an oxy-muriatic odour, and leaves much sediment.

Let a little of each solution be separately dropped into water. The true deposites oxide of antimony in a copious white coagulum; or, if the water has been previously tinged with sulphuret of ammonia, in a fine orange precipitate. The spurious gives no precipitate in water, and, in the other liquid, one of a dark brown or olive colour.

A solution of the spurious in distilled vinegar has a sweet taste, together with the other properties of acetate of lead.

A very small mixture of the spurious may be detected by its debasing, more or less, the bright orange colour of the precipitate thrown down by the sulphuret of ammonia from the solution in any acid.

The samples of the spurious, hitherto detected, are of a much thicker and clumsier cast than the genuine; but the appearance

* Philosophical Magazine, xxxv. 286.

is not to be trusted, and no specimen should be allowed to pass without a trial either of the specific gravity or chemical properties.

XXXI.—*Tartarized Antimony,—Antimonium Tartarizatum, P. L.—Emetic Tartar.*

A solution of this salt should afford, with acetate of lead, a precipitate perfectly soluble in dilute nitric acid. A few drops of the sulphuret of ammonia, also, should immediately precipitate a gold coloured sulphuret of antimony.

XXXII.—*Muriate of Mercury,—Hydrargyri Oxy-murias, P. L.—Corrosive Sublimate.*

If there be any reason to suspect arsenic in this salt, the fraud may be discovered as follows:—Dissolve a small quantity of the sublimate in distilled water; add a solution of carbonate of ammonia till the precipitate ceases, and filter the solution. If, on the addition of a few drops of ammoniated copper* to this solution, a precipitate of a yellowish green colour is produced, the sublimate contains arsenic.

XXXIII.—*Sub-muriate of Mercury,—Hydrargyri Sub-murias, P. L.—Calomel.*

Calomel should be completely saturated with mercury. This may be ascertained by boiling, for a few minutes, one part of calomel with $\frac{1}{32}$d part of muriate of ammonia (sal ammoniac) in 10 parts of distilled water. When carbonate of potash is added to the filtered solution, no precipitation will ensue if the calomel be pure. This preparation, when rubbed in an earthen mortar with pure ammonia, should become intensely black, and should exhibit nothing of an orange hue.

XXXIV.—*Mercury, or Quicksilver,—Hydrargyrus, P. L.*

Scarcely any substance is so liable to adulteration as mercury, owing to the property which it possesses of dissolving completely some of the baser metals. This union is so strong, that they even rise along with the quicksilver when distilled. The impurity of mercury is generally indicated by its dull aspect; by its tarnishing and becoming covered with a coat of oxide, on long exposure to the air; by its adhesion to the surface of glass; and, when shaken with water in a bottle, by the speedy formation of a black pow-

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* Prepared by digesting a little verdegris in the solution of pure ammonia.

der. Lead and tin are frequent impurities, and the mercury be-comes capable of taking up more of these if zinc or bismuth be previously added. In order to discover lead, the mercury may be agitated with a little water, in order to oxidize that metal. Pour off the water, and digest the mercury with a little acetous acid. This will dissolve the oxide of lead, which will be indicated by a blackish precipitate with sulphuretted water. Or, to this acetous solution, add a little sulphate of soda, which will precipitate a sulphate of lead, containing, when dry, 72 *per cent.* of metal. If only a very minute quantity of lead be present, in a large quantity of mercury, it may be detected by solution in nitric and the addi-tion of sulphuretted water. A dark brown precipitate will ensue, and will subside if allowed to stand a few days. One part of lead may thus be separated from 15263 parts of mercury.* Bismuth is detected by pouring a nitric solution, prepared without heat, in-to distilled water; a white precipitate will appear if this metal be present. Tin is manifested, in like manner, by a weak solution of nitro-muriate of gold, which throws down a purple sediment; and zinc, by exposing the metal to heat.

XXXV.—*Red Oxide of Mercury,—Hydrargyri Oxydum Ru-brum, P. L.*

This substance is rarely found adulterated, as it would be diffi-cult to find a substance well suited to this purpose. If well pre-pared, it may be totally volatilized by heat.

XXXVI.—*Red Oxide of Mercury by Nitric Acid,—Hydrargyri Nitrico Oxydum, P. L.—Red Precipitate.*

This is very liable to adulteration with minium, or red lead. The fraud may be discovered by digesting it in acetic acid, and adding to the solution sulphuretted water, or sulphuret of ammo-nia, either of which produces, with the compounds of lead, a dirty dark coloured precipitate. It should also be totally volatilized by heat.

XXXVII.—*White Oxide of Mercury,—Hydrargyrus Præcipita-tus Albus, P. L.—White Precipitate.*

White lead is the most probable adulteration of this substance, and chalk may also be occasionally mixed with it. The oxide of lead may be discovered as in the last article; and chalk, by add-ing to the dilute solution a little oxalic acid.

* See Mr. Accum's valuable papers on the detection of adulterations, in Nicholson's Journal, 4to.

XXXVIII.—*Red Sulphuretted Oxide of Mercury,—Hydrargyri Sulphuretum Rubrum, P. L.—Factitious Cinnabar.*

This substance is frequently adulterated with red lead, which may be detected by the foregoing rules. Chalk and dragon's blood are also sometimes mixed with it. The chalk is discovered by an effervescence on adding acetic acid, and by pouring oxalic acid into the acetous solution. Dragon's blood will be left unvolatilized when the sulphuret is exposed to heat, and may be detected by its giving a colour to alcohol, when the cinnabar is digested with it.

XXXIX.—*Black Sulphuretted Oxide of Mercury,—Ethiops Mineral.*

The mercury and sulphur, in this preparation, should be so intimately combined, that no globules of the metal can be discovered by a magnifier; and that, when rubbed on gold, no white stain may be communicated. The admixture of ivory-black may be detected by its not being wholly volatilized by heat; or, by boiling with alkali to extract the sulphur, and afterwards exposing the residuum to heat, which ought entirely to evaporate.

XL.—*Yellow Oxide or Sub-sulphate of Mercury,—Hydrargyrus Vitriolatus, P. L.—Turbith Mineral.*

This preparation should be wholly evaporable; and, when digested with distilled water, the water ought not to take up any sulphuric acid, which will be discovered by muriate of barytes.

XLI.—*Fused Nitrate of Silver,—Argenti Nitras, P. L.—Lunar Caustic.*

The most probable admixture with this substance is nitrate of copper, derived from the employment of an impure silver. In moderate proportion this is of little importance. It may be ascertained by solution in water, and adding an excess of pure ammonia, which will detect copper by a deep blue colour.

The watery solution of lunar caustic, when mingled with one of common salt, should give a copious curdy precipitate.

XLII.—*White Oxide of Zinc,—Zinci Oxydum, P. L.—Flowers of Zinc.*

Oxide of zinc may be adulterated with chalk, which is discoverable by an effervescence with acetous acid, and by the precipitation of this solution with oxalic acid. Lead is detected by add

ing, to the acetous solution, sulphuretted water, or sulphuret of ammonia. Arsenic, to which the activity of this medicine has been sometimes ascribed, is detected, also, by sulphuretted water, added to the acetous solution : but in this case the precipitate has a yellow colour, and, when laid on red-hot charcoal, gives first a smell of sulphur, and afterwards of arsenic.

XLIII.—*White Oxide of Lead,—Plumbi Carbonas, P. L.— White Lead.*

This is frequently sophisticated with chalk ; the presence of which may be detected by cold acetous acid, and by adding, to this solution, oxalic acid. Carbonate of barytes is detected by sulphate of soda added to the same solution, very largely diluted with distilled water ; and sulphate of barytes, or sulphate of lead, by the insolubility of the cerusse in boiling distilled vinegar.

XLIV.—*Superacetate of Lead,—Plumbi Superacetas, P. L.— Sugar of Lead.*

If the acetate of lead should be adulterated with acetate of lime or of barytes, the former may be detected by adding, to a dilute solution, the oxalic acid ; and the latter by sulphuric acid, or solution of sulphate of soda, added to a solution very largely diluted with water. Acetate of lead ought to dissolve entirely in water, and any thing that resists solution may be regarded as an impurity.

XLV.—*Green Oxide, or Sub-acetate of Copper,—Ærugo, P. L. —Verdegris.*

This substance is scarcely ever found pure, being mixed with pieces of copper, grape-stalks, and other impurities. The amount of this admixture of insoluble substances may be ascertained by boiling a portion of verdegris with 12 or 14 times its weight of distilled vinegar, allowing the undissolved part to settle, and ascertaining its amount. Sulphate of copper may be detected by boiling the verdegris with water, and evaporating the solution. Crystals of acetate of copper will first separate, and, when the solution has been farther concentrated, the sulphate of copper will crystallize. Or, it may be discovered by adding to the watery solution muriate of barytes, which will throw down a very abundant precipitate. Tartrate of copper, another adulteration sometimes met with, is discovered by dissolving a little of the verdegris in acetous acid, and adding acetate or muriate of barytes, which will afford, with the tartarous acid, a precipitate soluble in muriatic acid.

XLVI.—*Crystallized Acetate of Copper,—Distilled or Crystallized Verdegris.*

This is prepared by dissolving the common verdegris in distilled vinegar, and crystallizing the solution. These crystals should dissolve entirely in six times their weight of boiling water, and the solution should give no precipitation with solutions of barytes; for, if these solutions throw down a precipitate, sulphate of copper is indicated. This impurity, which I have frequently met with, may be discovered by evaporating the solution very low, and separating the crystals of acetate of copper. Farther evaporation and cooling will crystallize the sulphate, if any be present.

XLVII.—*Sub-carbonate of Magnesia,—Magnesiæ Carbonas, P. L.*

Carbonate of magnesia is most liable to adulteration with chalk; and, as lime forms with sulphuric acid a very insoluble salt, and magnesia one very readily dissolved, this acid may be employed in detecting the fraud. To a suspected portion of magnesia add a little sulphuric acid, diluted with eight or ten times its weight of water. If the magnesia should entirely be taken up, and the solution should remain transparent, it may be pronounced pure, but not otherwise. Another mode of discovering the deception is as follows :—Saturate a portion of the suspected magnesia with muriatic acid, and add a solution of carbonate of ammonia. If any lime be present, it will form an insoluble precipitate, but the magnesia will remain in solution.

XLVIII.—*Pure Magnesia,—Magnesia, P. L.—Calcined Magnesia.*

Calcined magnesia may be assayed by the same tests as the carbonate. It ought not to effervesce at all with dilute sulphuric acid; and, if the earth and acid be put together into one scale of a balance, no diminution of weight should ensue on mixing them together. It should be perfectly free from taste, and, when digested with distilled water, the filtered liquor should manifest no property of lime-water. Calcined magnesia, however, is very seldom so pure as to be totally dissolved by diluted sulphuric acid; for a small insoluble residue generally remains, consisting chiefly of siliceous earth, derived from the alkali. The solution in sulphuric acid, when largely diluted, ought not to afford any precipitation with oxalate of ammonia.

XLIX.—*Spirit of Wine, Alcohol, and Æthers.*

The only decisive mode of ascertaining the purity of spirit of wine and of æthers, is by determining their specific gravity. Highly rectified alcohol should have the specific gravity of 800 to 1000. Common spirit of wine 837. Sulphuric æther 739. The *spiritus ætheris sulphurici*, *P. L.* or sweet spirit of vitriol, about 753,—and nitric æther, the *spiritus ætheris nitrosus*, or sweet spirit of nitre, 908. The æthers ought not to redden the colour of litmus, nor ought those formed from sulphuric acid to give any precipitation with solution of barytes.

L.—*Essential or Volatile Oils.*

As essential oils constitute only a very small proportion of the vegetables from which they are obtained, and bear generally a very high price, there is a considerable temptation to adulterate them. They are found sophisticated, either with cheaper volatile oils, with fixed oils, or with the spirit of wine. The fixed oils are discovered by distillation with a very gentle heat, which elevates the essential oils, and leaves the fixed ones. These last may, also, be detected by moistening a little writing-paper with the suspected oil, and holding it before the fire. If the oil be entirely essential, no stain will remain on the paper. Alcohol, also, detects the fixed oils, because it only dissolves the essential ones, and the mixture becomes milky. The presence of cheaper essential oils is discovered by the smell. Alcohol, a cheaper liquid than some of the most costly oils, is discovered by adding water, which, if alcohol be present, occasions a milkiness.

CHAPTER III.

USE OF CHEMICAL RE-AGENTS TO CERTAIN ARTISTS AND MANUFACTURERS.

TO point out all the beneficial applications of chemical substances to the purposes of the arts, would require a distinct and very extensive treatise. In this place I have no farther view than to describe the mode of detecting adulterations in certain articles of commerce ; the strength and purity of which are essential to the success of chemical processes.

I.—*Mode of detecting the Adulteration of Potashes, Pearlashes,*
and Barilla.

Few objects of commerce are sophisticated to a greater extent
than the alkalis, to the great loss and injury of the bleacher, the
dyer, the glass-maker, the soap-boiler, and of all other artists who
are in the habit of employing these substances. In the first part
of this work (see vol. i. page 223) I have already given rules for
discovering such adulterations : and to what has been said, I ap-
prehend it is only necessary to add the directions of Mr. Kirwan,
intended to effect the same end, but differing in the mode. They
are transcribed from his paper, entitled, " Experiments on the Al-
kaline Substances used in Bleaching ;"—see Transactions of the
Irish academy for 1789.*

" To discover whether any quantity of fixed alkali worthy of at-
tention exists in any saline compound, dissolve one ounce of it in
boiling water, and into this solution let fall a drop of a solution of
sublimate corrosive ; this will be converted into a brick-colour, if
an alkali be present, or into a brick-colour mixed with yellow, if
the substance tried contains lime.

" But the substances used by bleachers being always impreg-
nated with an alkali, the above trial is in general superfluous, ex-
cept for the purpose of detecting lime. The quantity of alkali is
therefore what they should chiefly be solicitous to determine, and
for this purpose,

" 1st, Procure a quantity of alum, suppose one pound, reduce
it to powder, wash it with cold water, and then put it into a tea-
pot, pouring on it three or four times its weight of boiling water.

" 2dly, Weigh an ounce of the ash or alkaline substance to be
tried, powder it, and put it into a Florence flask with one pound of
pure water (common water, boiled for a quarter of an hour, and
afterwards filtered through paper, will answer ;) if the substance
to be examined be of the nature of barilla or potash, or half a pound
of water if it contain but little earthy matter, as pearlash. Let
them boil for a quarter of an hour ; when cool, let the solution be
filtered into another Florence flask.

" 3dly, This being done, gradually pour the solution of alum
hot into the alkaline solution also heated ; a precipitation will im-
mediately appear ; shake them well together, and let the efferves-

* Directions for the assay of potash, by the intervention of nitrate of
strontites, may be found in the 41st volume of the *Annales de Chimie,* page
113.

cence, if any, cease before more of the aluminous solution be added; continue the addition of the alum until the mixed liquor, when clear, turns syrup of violets or paper tinged blue by radishes, or by litmus, red; then pour the liquor and precipitate on a paper-filter, placed in a glass funnel. The precipitated earth will remain on the filter; pour on this a pound or more of hot water, gradually, until it passes tasteless; take up the filter, and let the earth dry on it until they separate easily. Then put the earth into a cup of Staffordshire ware, place it on hot sand, and dry the earth until it ceases to stick to glass or iron; then pound it, and reduce it to powder in the cup with a glass pestle, and keep it a quarter of an hour in a heat of from 470° to 500°.

" 4thly, The earth being thus dried, throw it into a Florence flask, and weigh it; then put about one ounce of spirit of salt into another flask, and place this in the same scale as the earth, and counterbalance both in the opposite scale; this being done, pour the spirit of salt gradually into the flask that contains the earth; and, when all effervescence is over (if there be any,) blow into the flask, and observe what weight must be added to the scale containing the flasks to restore the equilibrium; subtract this weight from that of the earth, the remainder is a weight exactly *proportioned* to the weight of mere alkali of that particular species which is contained in one ounce of the substance examined; all beside is superfluous matter.

" I have said, that alkalis of the *same species* may thus be directly compared, because alkalis of *different* species cannot but require the intervention of another proportion; and the reason is, because *equal* quantities of alkalis of different species precipitate unequal quantities of earth of alum: Thus 100 parts, by weight, of mere vegetable alkali precipitate 78 of earth of alum, but 100 parts of *mineral* alkali precipitate 170.8 parts of that earth. Therefore the precipitation of 78 parts of earth of alum, by vegetable alkali, denotes as much of this, as the precipitation of 170.8 of that earth by the mineral alkali, denotes of the mineral alkali. Hence the quantities of alkali in all the different species of potashes, pearl-ashes, weed or wood ashes, may be immediately compared with the above test, as they all contain the vegetable alkali; and the different kinds of kelp or kelps manufactured in different places, and the different sorts of barilla, may thus be compared, because they all contain the mineral alkali. But kelps and potashes, as they contain different sorts of alkali, can only be compared together by means of the proportion above indicated."

II.—*Mode of detecting the Adulteration of Manganese.*

In the section on drugs, instructions may be found for discovering impurities in several chemical preparations, employed by the artist, as cerusse or white lead, red lead, verdegris, &c. No rules, however, have been given for examining manganese, which is a substance that varies much in quality, and is often sophisticated ; as the bleachers experience, to their no small disappointment and loss.

The principle defect of the manganese arises from the admixture of chalk, which is not always an intentional adulteration, but is sometimes found united with it, as it occurs in the earth. When to this impure manganese mixed with muriate of soda, the sulphuric acid is added, the materials effervesce and swell considerably, and a large proportion passes into the receiver ; in consequence of which the bleaching liquor is totally spoiled. This accident has, to my knowledge, frequently happened, and can only be prevented by so slow and cautious an addition of the acid, as is nearly inconsistent with the business of an extensive bleaching work. The presence of carbonate of lime may be discovered in manganese, by pouring, on a portion of this substance, nitric acid diluted with 8 or 10 parts of water. If the manganese be good, no effervescence will ensue, nor will the acid dissolve any thing ; but, if carbonate of lime be present, it will be taken up by the acid. To the solution add a sufficient quantity of carbonate of potash to precipitate the lime, wash the sediment with water, and dry it. Its weight will show how much chalk the manganese under examination contained.

Another adulteration of manganese, that may, perhaps, be sometimes practised, is the addition of some ores of iron. This impurity is less easily discovered. But if the iron be in such a state of oxidation as to be soluble in muriatic acid, the following process may discover it. Dissolve a portion, with the assistance of heat, in concentrated muriatic acid, dilute the solution largely with distilled water, and add a solution of crystallized carbonate of potash. The manganese will remain suspended, by the excess of carbonic acid, on mixing the two solutions, but the iron will be precipitated in the state of a coloured oxide.

From an observation of Klaproth (Essays, vol. i. page 572,) it appears that oxides of iron and manganese are separable by nitrous acid with the addition of sugar, which takes up the manganese only.

CHAPTER IV.

APPLICATION OF CHEMICAL TESTS TO THE USES OF THE FARM-
ER AND COUNTRY GENTLEMAN.

THE benefits that might be derived from the union of chemical
skill, with the extensive observation of agricultural facts, are, per-
haps, incalculable. At present, however, the state of knowledge
among farmers, is not such as to enable them to reap much advan-
tage from chemical experiments; and the chemist has, himself,
scarcely ever opportunities of applying his knowledge to practical
purposes in this way. It may, perhaps, however, be of use, to of-
fer a few brief directions for the analysis of marls, lime-stones, &c.

SECTION I.

Lime.

IT is impossible to lay down any general rules respecting the
fitness of lime for the purposes of agriculture; because much
must depend on the peculiarities of soil, exposure, and other cir-
cumstances. Hence a species of lime may be extremely well a-
dapted for one kind of land and not for another. All that can be
accomplished by chemical means is to ascertain the degree of pu-
rity of the lime, and to infer, from this, to what kind of soil it is
best adapted. Thus a lime, which contains much argillaceous
earth, is better adapted than a purer one to dry and gravelly soils;
and stiff clayey lands require a lime as free as possible from the
argillaceous ingredient.

To determine the purity of lime, let a given weight be dissolv-
ed in diluted muriatic acid. Let a little excess of acid be added,
that no portion may remain undissolved owing to the deficiency of
the solvent. Dilute with distilled water; let the insoluble part,
if any, subside, and the clear liquor be decanted. Wash the sedi-
ment with farther portions of water, and pour it upon a filter, pre-
viously weighed. Dry the filter and ascertain its increase of
weight, which will indicate how much insoluble matter the quan-
tity of lime submitted to experiment contained. It is easy to
judge by the external qualities of the insoluble portion, whether
argillaceous earth abounds in its composition.

There is one earth, however, lately found in several lime-stones,
which is highly injurious to the vegetation of plants, and is not
discoverable by the foregoing process, being, equally with lime,

soluble in muriatic acid. This earth is magnesia, which, by direct experiments, has been ascertained to be extremely noxious to plants. Mr. Tennant, the gentleman to whom we owe this fact, was informed, that in the neighbourhood of Doncaster two kinds of lime were employed, one of which it was necessary to use very sparingly, and to spread very evenly ; for it was said, that a large proportion, instead of increasing, diminished the fertility of the soil ; and that, whenever a heap of it was left in one spot, all fertility was prevented for many years. Fifty or sixty bushels on an acre were considered to be as much as could be used with advantage. The other sort of lime, which was obtained from a village near Ferrybridge, though considerably dearer, from the distant carriage, was more frequently employed, on account of its superior utility. A large quantity was never found to be injurious ; and the spots which were covered with it, instead of being rendered barren, became remarkably fertile. On examining the composition of these two species of lime, the fertilizing one proved to consist entirely of calcareous earth, and the noxious one of three parts lime and two magnesia.

The presence of magnesia in lime proved, on farther investigation, to be a very common occurrence. The magnesian limestone appears to extend for 30 or 40 miles from a little south-west of Worksop, in Nottinghamshire, to near Ferrybridge, in Yorkshire, and it has also been found at Breedon and Matlock, in Derbyshire.

The magnesian lime-stone, according to Mr. Tennant, may easily be distinguished from that which is purely calcareous, by the slowness of its solution in acids, which is so considerable, that even the softest kind of the former is much longer in dissolving than marble. It has also frequently a crystallized structure, and sometimes, though not always, small black dots may be seen dispersed through it. In the countries where this lime-stone is found, the lime is generally distinguished, from its effects in agriculture by the farmers, as *hot* lime, in opposition to the purely calcareous, which they term *mild*.

To ascertain, by chemical means, the composition of a lime or lime-stone suspected to contain magnesia, the following is the easiest, though not the most accurate, process. Procure a Florence flask, clean it well from oil by a little soap-lees or salt of tartar and quicklime mixed, and break it off, about the middle of the body, by setting fire to a string tied round it and moistened with oil of turpentine. Into the bottom part of this flask put 100 grains of

the lime or lime-stone, and pour on it, by degrees, half an ounce of strong sulphuric acid. On each affusion of acid a violent effervescence will ensue; when this ceases, stir the acid and lime together with a small glass tube, or rod, and place the flask in an iron pan, filled with sand. Set it over the fire, and continue the heat, till the mass is quite dry. Scrape off the dry mass, weigh it, and put it into a wine glass, which may be filled up with water. Stir the mixture, and when it has stood half an hour, pour the whole on a filtering-paper, placed on a funnel, and previously weighed. Wash the insoluble part with water, as it lies on the filter, and add the washings to the filtered liquor. To this liquor add a solution of half an ounce of salt of tartar in water, when, if magnesia be present, a very copious white sediment will ensue, if lime only, merely a slight milkiness. In the former case, heat the liquor by setting it in a tea-cup near the fire; let the sediment subside; pour off the clear liquor, which may be thrown away, and wash the white powder repeatedly with warm water. Then pour it on a filter of paper, the weight of which is known, dry it, and weigh. The result, if the lime-stone has been submitted to experiment, shows how much carbonate of magnesia was contained in the original stone, or, deducting 60 *per cent.* how much pure magnesia 100 parts of the lime-stone contained. If the burnt lime has been used, deduct from the weight of the precipitate 60 *per cent.* and the remainder will give the weight of the magnesia in each 100 grains of the burnt lime.

SECTION II.

Analysis of Marls.

THE ingredient of marls, on which their fitness for agricultural purposes depends, is the carbonate of lime. It is owing to the presence of this earth that marls effervesce on the addition of acids, which is one of their distinguishing characters. In ascertaining whether an effervescence takes place, let the marl be put into a glass, partly filled with water, which will expel a portion of air contained mechanically in the marl, and thus obviate one source of fallacy. When the marl is thoroughly penetrated by the water, add a little muriatic acid, or spirit of salt. If a discharge of air should ensue, the marly nature of the earth is sufficiently established.

To find the composition of a marl, pour a few ounces of diluted muriatic acid into a Florence flask, place them in a scale, and let

them be balanced. Then reduce a few ounces of marl into dry powder, and let this powder be carefully and gradually thrown into the flask, until, after repeated additions, no farther effervescence is perceived. Let the remainder of the powdered marl be weighed, by which the quantity projected will be known. Let the balance be then restored. The difference of weight between the quantity projected and that requisite to restore the balance, will show the weight of air lost during effervescence. If the loss amount to 13 *per cent.* of the quantity of marl projected, or from 13 to 32 *per cent.* the marl assayed is calcareous marl, or marl rich in calcareous earth.

Clayey marls, or those in which the argillaceous ingredient prevails, lose only 8 or 10 *per cent.* of their weight by this treatment, and sandy marls about the same proportion. The presence of much argillaceous earth may be judged by drying the marl, after being washed with spirit of salt, when it will harden and form a brick.

To determine, with still greater precision, the quantity of calcareous earth in a marl, let the solution in muriatic acid be filtered, and mixed with a solution of carbonate of potash, till no farther precipitation appears. Let the sediment subside, wash it well with water, lay it on a filter, previously weighed, and dry it. The weight of the dry mass will show how much carbonate of lime the quantity of marl submitted to experiment contained.

SECTION III.

Analysis of Soils.

THE following rules, for determining the composition of a soil, are copied from a memoir, presented by Mr. Davy to the Board of Agriculture.

I.—*Utility of Investigations relating to the Analysis of Soils.*

The methods of improving lands are immediately connected with the knowledge of the chemical nature of soils, and experiments on their composition appear capable of many useful applications.

The importance of this subject has been already felt by some very able cultivators of science ; many useful facts and observations, with regard to it, have been furnished by Mr. Young ; it has been examined by Lord Dundonald, in his Treatise on the Connexion of Chemistry with Agriculture, and by Mr. Kirwan in

his excellent essay on Manures ; but the inquiry is still far from being exhausted, and new methods of elucidating it are almost continually offered, in consequence of the rapid progress of chemical discovery.

In the following pages I shall have the honour of laying before the Board, an account of those methods of analyzing soils which appear most precise and simple, and most likely to be useful to the practical farmer ; they are founded partly upon the labours of the gentlemen, whose names have been just mentioned, and partly upon some later improvements.

II.—*Of the Substances found in Soils.*

The substances, which are found in soils, are certain mixtures or combinations of some of the primitive earths, animal and vegetable matter in a decomposing state, certain saline compounds, and the oxide of iron. These bodies always retain water, and exist in very different proportions in different lands ; and the end of analytical experiments is the detection of their quantities and mode of union.

The *earths* found in common soils are principally silex, or the earth of flints, alumine, or the pure matter of clay, lime, or calcareous earth, and magnesia.

Silex, or the earth of flints, when perfectly pure, appears in the form of a white powder, which is incombustible, infusible, insoluble in water, and not acted upon by common acids ; it is the substance which constitutes the principal part of rock crystal; it composes a considerable part of hard gravelly soils, of hard sandy soils, and of hard stony lands.

Alumine, or pure clay, in its perfect state is white like silex ; it adheres strongly to the tongue, is incombustible, insoluble in water, but soluble in acids, and in fixed alkaline menstrua. It abounds most in clayey soils and clayey loams ; but even in the smallest particles of these soils it is usually united to silex and oxide of iron.

Lime is the substance well known in its pure state under the name of quicklime. It always exists in soils in combination, and that principally with fixed air or carbonic acid, when it is called carbonate of lime ; a substance which in the most compact form constitutes marble, and in its looser form chalk. Lime, when combined with sulphuric acid (oil of vitriol,) produces sulphate of lime (gypsum,) and with phosphoric acid, phosphate of lime.

The carbonate of lime, mixed with other substances, composes chalky soils and marls, and it is found in soft sandy soils.

Magnesia, when pure, appears as white, and in a lighter powder, than any of the other earths ; it is soluble in acid, but not in alkaline menstrua ; it is rarely found in soils ; when it does exist, it is either in combination with carbonic acid, or with silex and alumine.

Animal decomposing matter exists in very different states, according as the substances from which it is produced are different ; it contains much carbonaceous substance ; and may be principally resolved by heat into this substance, volatile alkali, inflammable aëriform products, and carbonic acid ; it is principally found in lands that have lately been manured.

Vegetable decomposing matter is likewise very various in kind, it contains usually more carbonaceous substance than animal matter, and differs from it in the results of its decomposition, principally in not producing volatile alkali ; it forms a great proportion of all peats ; it abounds in rich mould, and is found in larger or smaller quantities in all lands.

The *saline compounds* found in soils are very few, and in quantities so small, that they are rarely to be discovered. They are principally muriate of soda (common salt,) sulphate of magnesia (Epsom salt,) and muriate and sulphate of potash, nitrate of lime, and the mild alkalis.

The *oxide of iron* is the same with the rust produced by exposing iron to the air in water ; it is found in all soils, but is most abundant in yellow and red clays, and in yellow and red siliceous sands.

III.—*Instruments required for the Analysis of Soils.*

The really important instruments required for the analysis of soils are few, and but little expensive. They are a balance capable of containing a quarter of a pound of common soil, and capable of turning when loaded, with a grain ; a series of weights from a quarter of a pound Troy to a grain ; a wire sieve, sufficiently coarse to admit a pepper corn through its apertures ; an Argand lamp and stand ; some glass bottles ; Hessian crucibles ; porcelain, or queen's ware evaporating basons ; a Wedgwood pestle and mortar ; some filters made of half a sheet of blotting-paper, folded so as to contain a pint of liquid, and greased at the edges ; a bone knife, and an apparatus for collecting and measuring aëriform fluids.

The chemical substances, or re-agents, required for separating the constituent parts of the soil, are muriatic acid (spirit of salt,) sulphuric acid, pure volatile alkali dissolved in water, solution of prussiate of potash, soap lye, solution of carbonate of ammonia, of muriate of ammonia, solution of neutral carbonate of potash, and nitrate of ammonia. An account of the nature of these bodies, and their effects, may be found in the chemical works already noticed; and the re-agents are sold, together with the instruments mentioned above, by Mr. Knight, Foster-lane, Cheapside, arranged in an appropriate chest.

IV.—*Mode of collecting Soils for Analysis.*

In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It sometimes happens, that upon plains the whole of the upper stratum of the land is of the same kind, and in this case, one analysis will be sufficient; but in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs that one part of a field is calcareous, and another part siliceous; and in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

Soils when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground glass stoppers.

The quantity of soil, most convenient for a perfect analysis, is from two to four hundred grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil; and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water will give the result. Thus if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2, that is, it will be twice as heavy as water, and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000.

It is of importance, that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains ; these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote, to a certain extent, their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it ; aluminous soils adhere strongly to the tongue, and emit a strong earthy smell when breathed on ; and calcareous soils are soft, and much less adhesive than aluminous soils.

V.—*Mode of ascertaining the Quantity of Water of Absorption in Soils.*

Soils, though as dry as they can be made by continued exposure to air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without in other respects affecting its composition ; and this may be done by heating it for ten or twelve minutes over an Argand's lamp, in a bason of porcelain, to a temperature equal to 300°* Fahrenheit ; and in case a thermometer is not used, the proper degree may be easily ascertained, by keeping a piece of wood in contact with the bottom of the dish ; as long as the colour of the wood remains unaltered, the heat is not too high ; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative results ; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and in consequence the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted ; and when in 400 grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will generally be found to contain a large proportion of aluminous earth. When the loss is only from 20 to 10,

* In several experiments, in which this process has been carried on by distillation, I have found the water that came over pure, and no sensible quantity of other volatile matter was produced.

the land may be considered as only slightly absorbent and reten-
tive, and the siliceous earth as most abundant.

VI.—*Of the Separation of Stones, Gravel, and Vegetable Fibres,* *from Soils.*

None of the loose stones, gravel, or large vegetable fibres should
be divided from the pure soil till after the water is drawn off; for
these bodies are themselves often highly absorbent and retentive,
and in consequence influence the fertility of the land. The next
process, however, after that of heating, should be their separation,
which may be easily accomplished by the sieve, after the soil has
been gently bruised in a mortar. The weights of the vegetable
fibres or wood, and of the gravel and stones, should be separately
noted down, and the nature of the last ascertained; if calcareous,
they will effervesce with acids; if siliceous, they will be sufficient-
ly hard to scratch glass; and if of the common aluminous class of
stones, they will be soft, easily scratched with a knife, and incapa-
ble of effervescing with acids.

XII.—*Separation of the Sand and Clay, or Loam, from each* *other.*

The great number of soils, besides gravel and stones, contain
larger or smaller proportions of sand of different degrees of fine-
ness; and it is a necessary operation, the next in the process of
analysis, to detach them from the parts in a state of more minute
division, such as clay, loam, marl, and vegetable and animal mat-
ter. This may be effected in a way sufficiently accurate, by agi-
tation of the soil in water. In this case, the course sand will gen-
erally separate in a minute, and the finer in two or three minutes,
whilst the minutely divided earthy, animal, or vegetable matter,
will remain in a state of mechanical suspension for a much longer
time; so that, by pouring the water from the bottom of the vessel,
after one, two, or three minutes, the sand will be principally sepa-
rated from the other substances, which, with the water containing
them, must be poured into a filter, and after the water has passed
through, collected, dried, and weighed. The sand must likewise
be weighed, and their respective quantities noted down. The wa-
ter of lixiviation must be preserved, as it will be found to contain
the saline matter, and the soluble animal or vegetable matters, if
any exist in the soil.

VIII.—*Examination of the Sand.*

By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones or gravel. It is always either siliceous sand, or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic acid, with effervescence ; but if it consist partly of this substance, and partly of siliceous matter, the respective qualities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part : it must be washed, dried, and heated strongly in a crucible ; the difference between the weight of it and the weight of the whole, indicates the proportion of calcareous sand.

IX.—*Examination of the finely divided Matter of Soils, and Mode of detecting mild Lime and Magnesia.*

The finely divided matter of the soil is usually very compound in its nature ; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter ; and to ascertain the proportions of these with tolerable accuracy, is the most difficult part of the subject.

The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of the muriatic acid. This substance should be poured upon the earthy matter in an evaporating bason, in a quantity equal to twice the weight of the earthy matter, but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

If any carbonate of lime, or of magnesia, exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron, but very seldom any alumine.

The fluid should be passed through a filter ; the solid matter collected, washed with rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solution, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of common prussiate of potash must be mixed with the whole. If a blue precipitate occurs, it denotes the

presence of oxide of iron, and the solution of the prussiate must be dropped in till no farther effect is produced. To ascertain its quantity, it must be collected in the same manner as other solid precipitates, and heated red ; the result is oxide of iron.

Into the fluid, freed from oxide of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alkaline salt.

The precipitate that falls down is carbonate of lime ; it must be collected on the filter, and dried at a heat below that of redness.

The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid, and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumine should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling for a few minutes with soap lye, sufficient to cover the solid matter.—This substance dissolves alumine, without acting upon carbonate of lime.

Should the finely divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid. *i. e.* about 45 *per cent. ;* so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid, is known, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

When the process by diminution of weight is employed, two parts of the acid, and one part of the matter of the soil must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases ; the difference between their weight before and after the experiment, denotes the quantity of carbonic acid lost ; for every four grains and a half of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by the pneumatic apparatus, the construction and application of which is described at the end of this paper.

The estimation is, for every ounce measure of carbonic acid, two grains of carbonate of lime.

X.—*Mode of ascertaining the Quantity of insoluble finely divided Animal and Vegetable Matter.*

After the fine matter of the soil has been acted upon by muriatic acid, the next process is to ascertain the quantity of finely divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by heating it to strong ignition in a crucible over a common fire till no blackness remains in the mass. It should be often stirred with a metallic wire, so as to expose new surfaces continually to the air; the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by fire and air.

It is not possible to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some animal matter; and a copious blue flame at the time, of ignition, almost always denotes a considerable proportion of vegetable matter. In cases when the experiment is needed to be very quickly performed, the destruction of the decomposible substances may be assisted by the agency of nitrate of ammonia, which, at the time of ignition, may be thrown gradually upon the heated mass, in the quantity of twenty grains for every hundred of residual soil. It affords the principle necessary to the combustion of the animal and vegetable matter, which it causes to be converted into elastic fluids; and is itself at the same time decomposed and lost.

XI.—*Mode of separating Aluminous and Siliceous Matter, and Oxide of Iron.*

The substances remaining after the decomposition of the vegetable and animal matter, are generally minute particles of earthy matter, containing usually alumine and silex with combined oxide of iron.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or one hundred and twenty grains of acid.

The substance, remaining after the action of the acid, may be

considered as siliceous ; and it must be separated, and its weight ascertained, after washing and drying in the usual manner.

The alumine and the oxide of iron, if any exist, are both dissolved by the sulphuric acid ; they may be separated by carbonate of ammonia, added to excess ; it throws down the alumine, and leaves the oxide of iron in solution, and this substance may be separated from the liquid by boiling.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid ; this, however, is scarcely ever the case ; but the process for detecting them and ascertaining their quantities, is the same in both instances.

The method of analysis by sulphuric acid, is sufficiently precise for all usual experiments ; but if very great accuracy be an object, dry carbonate of potash must be employed as the agent, and the residuum of the incineration must be heated red for a half hour, with four times its weight of this substance, in a crucible of silver, or of well baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid ; distilled water must then be added, by which the oxide of iron and all the earths, except silex, will be dissolved in combination as muriates. The silex, after the usual process of lixiviation, must be heated red ; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

XII.—*Mode of discovering soluble Animal and Vegetable Matter, and Saline Matter.*

If any saline matter, or soluble vegetable or animal matter, is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in an appropriate dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour, and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be strong and fetid, it contains animal mucilaginous or gelatinous substance ; if it be white and transparent, it may be considered as principally saline matter. Nitrate of potash (nitre) or nitrate of lime, is indicated in this saline matter, by its scintillating with a burning coal. Sulphate of magne-

sia may be detected by its bitter taste; and sulphate of potash produces no alteration in solution of carbonate of ammonia, but precipitates solution of muriate of barytes.

XIII.—*Mode of detecting Sulphate of Lime (Gypsum) and Phosphate of Lime in Soils.*

Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance four hundred grains, must be heated red for half an hour in a crucible mixed with one third of powdered charcoal. The mixture must be boiled for a quarter of an hour, in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any soluble quantity of sulphate of lime (gypsum) existed in the soil, a white precipitate will gradually form in the fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths; the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

It would not fall within the limits assigned to this paper, to detail any processes for the detection of substances which may be accidentally mixed with the matters of soils. Manganese is now and then found in them, and compounds of the barytic earth; but these bodies appear to bear little relation to fertility or barrenness, and the search for them would make the analysis much more complicated without rendering it more useful.

XIV.—*Statement of Results and Products.*

When the examination of a soil is completed, the products should be classed, and their quantities added together, and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime are discovered by the independent process XIII. a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime, obtained by precipitation from the muriatic acid.

In arranging the products, the form should be in the order of the experiments by which they are obtained.

Thus 400 grains of a good siliceous sandy soil may be supposed to contain

	Grains.
Of water of absorption - - - - - -	18
Of loose stones and gravel, principally siliceous - -	42
Of undecompounded vegetable fibres - - - -	10
Of fine siliceous sand - - - - - -	200
Of minutely divided matter separated by filtration, and consisting of	
Carbonate of lime - - - - - 25	
Carbonate of magnesia - - - - 4	
Matter destructible by heat, principally veg-⎱ etable ⎰ 10	
Silex - - - - - - - 40	
Alumine - - - - - - - 32	
Oxide of iron - - - - - - 4	
Soluble matter, principally sulphate of potash ⎱ and vegetable extract ⎰ 5	
Gypsum - - - - - - - 3	
Phosphate of lime - - - - - 2	
	125
Amount of all the products -	395
Loss - - - - -	5

In this instance the loss is supposed small ; but in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates ; and when it is within thirty for four hundred grains, there is no reason to suspect any want of due precision in the processes.

XV.—*This general Method of Analysis may, in many Cases, be much simplified.*

When the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid IX. may be omitted. In examining peat soils, he will principally have to attend to the operation by

fire and air X.; and in the analysis of chalks and loams, he will often be able to omit the experiment by sulphuric acid XI.

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with: but, in overcoming them, the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science, as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn from books, the history of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operation, and acquired for the purpose of discovery.

XVI.—*On the Improvement of Soils, as connected with the Principle of their Composition.*

In cases when a barren soil is examined with a view to its improvement, it ought, in all cases, if possible, to be compared with an extremely fertile soil in the same neighbourhood, and in a similar situation: the difference given by their analysis would indicate the methods of cultivation; and thus the plan of improvement would be founded upon accurate scientific principles.

If the fertile soil contained a large quantity of sand, in proportion to the barren soil, the process of amelioration would depend simply upon a supply of this substance; and the method would be equally simple with regard to soils deficient in clay or calcareous matter.

In the application of clay, sand, loam, marl, or chalk, to lands, there are no particular chemical principles to be observed; but when quicklime is used, great care must be taken that it is not obtained from the magnesian lime-stone; for in this case, as has been shown by Mr. Tennant, it is exceedingly injurious to land.[*] The magnesian lime-stone may be distinguished from the common lime-stone by its greater hardness, and by the length of time that it requires for its solution in acids; and it may be analyzed by the process for carbonate of lime and magnesia, IX.

When the analytical comparison indicates an excess of vegetable matter, as the cause of sterility, it may be destroyed by much

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[*] Philosophical Transactions for 1799, page 305. This lime-stone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

pulverization and exposure to air, by paring and burning, or the agency of lately-made quick-lime. And the defect of animal and vegetable matter must be supplied by animal or vegetable manure.

XVII.—*Sterile Soils in different Climates and Situations must differ in Composition.*

The general indications of fertility and barrenness, as found by chemical experiments, necessarily must differ in different climates, and under different circumstances. The power of soils to absorb moisture, a principal essential to their productiveness, ought to be much greater in warm and dry countries, than in cold and moist ones; and the quantity of fine aluminous earth they contain larger. Soils, likewise, that are situated on declivities, ought to be more absorbent than those in the same climate on plains or in valleys.* The productiveness of soils must likewise be influenced by the nature of the subsoil, or the earthy or stony strata on which they rest; and this circumstance ought to be particularly attended to, in considering their chemical nature, and the system of improvement. Thus a sandy soil may sometimes owe its fertility to the power of the subsoil to retain water; and an absorbent clayey soil may occasionally be prevented from being barren, in a moist climate, by the influence of a substratum of sand or gravel.

XVIII.—*Of the Chemical Composition of fertile Corn Soils in this Climate.*

Those soils that are most productive of corn, contain always certain proportions of aluminous and calcareous earth in a finely divided state, and a certain quantity of vegetable or animal matter.

The quantity of calcareous earth is however very various, and in some cases exceedingly small. A very fertile corn soil from Ormiston, in East Lothian, afforded me, in an hundred parts, only eleven parts of mild calcareous earth; it contained twenty-five parts of siliceous sand; the finely divided clay amounted to forty-five parts. It lost nine in decomposed animal and vegetable matter, and four in water, and afforded indications of a small quantity of phosphate of lime.

This soil was of a very fine texture, and contained very few stones or vegetable fibres. It is not unlikely that its fertility was

* Kirwan, Transactions of the Irish Academy, v. 175.

in some measure connected with the phosphate; for this substance is found in wheat, oats, and barley, and may be a part of their food.

A soil from the low lands of Somersetshire, celebrated for producing excellent crops of wheat and beans without manure, I found to consist of one ninth of sand, chiefly siliceous, and eight ninths of calcareous marl, tinged with iron, and containing about five parts in the hundred of vegetable matter. I could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere.[*]

Mr. Tillet, in some experiments made on the composition of soils at Paris, found that a soil composed of three eighths of clay, two eighths of river sand, and three eighths of the parings of limestone, was very proper for wheat.

XIX.—Of the Composition of Soils proper for bulbous Roots and for Trees.

In general, bulbous roots require a soil much more sandy and less absorbent, than the grasses. A very good potatoe soil, from Varfel, in Cornwall, afforded me seven eighths of siliceous sand : and its absorbent power was so small, that 100 parts lost only two by drying at 400° Fahrenheit.

Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deep into the earth, will vegetate to advantage in almost all common soils which are moderately dry, and which do not contain a very great excess of vegetable matter.

I found the soil taken from a field at Sheffield-place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely divided matter; and one hundred parts of the entire soil, submitted to analysis, produced,

Water - - - - - -	3 parts
Silex - - - - - -	54
Alumine - - - - - -	28
Carbonate of lime - - - -	3
Oxide of iron - - - - -	5
Decomposing vegetable matter - -	4
Loss - - - - - -	3

* This soil was sent to me by T. Poole, Esq. of Nether Stowey. It is near the opening of the river Parret into the British Channel; but, I am told, is never overflowed.

XX.—*Advantages of Improvements made by changing the Composition of Earthy Parts of Soils.*

From the great difference of the causes that influence the productiveness of lands, it is obvious, that, in the present state of science, no certain system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of amelioration; and this will particularly happen, when the defect of composition is found in the proportions of the primitive earths.

In supplying animal or vegetable manure, a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops; but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expense.

Description of the Apparatus for the Analysis of Soils.

Pl. iv. fig. 44; *a, b, c, d, e, f.* The different parts of the apparatus required for measuring the quantity of elastic fluid given out during the action of an acid on calcareous soils. *a* Represents the bottle for containing the soil; *b*, the bottle containing the acid, furnished with a stop-cock; *c*, the tube connected with the flaccid bladder; *d, f,* the graduated measure; *e,* the bottle for containing the bladder. When this instrument is used, a given quantity of soil is introduced into *a;* *b*, is filled with muriatic acid, diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of *a*, which is ground to receive it. The tube *c* is introduced into the lower orifice of *a*, and the bladder connected with it placed in its flaccid state in *e*, which is filled with water. The graduated measure is placed under the tube of *e*. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid generated passes through *e* into the bladder, and displaces a quantity of water in *e* equal to it in bulk, and this water flows through the tube into the graduated measure; the water in which gives, by its volume, the indication of the proportion of carbonic acid disengaged from the soil; for every ounce measure of which two grains of carbonate of lime may be estimated.

CHAPTER V.

MISCELLANEOUS USES OF CHEMICAL RE-AGENTS.

I.—*Removal of Ink Stains.*

THE stains of ink on cloth, paper, or wood, may be removed by almost all acids ; but those acids are to be preferred which are least likely to injure the texture of the stained substance. The muriatic acid, diluted with five or six times its weight of water, may be applied to the spot, and, after a minute or two, may be washed off, repeating its application as often as may be found necessary. But the vegetable acids are attended with less risk, and are equally effectual. A solution of the oxalic, citric, or tartaric acids, in water, may be applied to the most delicate fabrics, without any danger of injuring them; and the same solutions discharge from paper, written, but not printed, ink. Hence they may be employed in cleaning books, which have been defaced by writing on the margin, without impairing the text.

II.—*Iron Stains.*

These may be occasioned either by ink stains, which, on the application of soap, are changed into iron stains, or by the direct contact of rusted iron.—They may be removed by diluted muriatic acid, or by one of the vegetable acids already mentioned. When suffered to remain long on cloth, they become extremely difficult to take out, because the iron, by repeated moistening with water and exposure to the air, acquires such an addition of oxygen as renders it insoluble in acids. Even these spots, however, may be discharged, by applying first a solution of recently prepared muriate of tin, which must be well washed from the cloth, and afterwards a liquid acid. The muriate of tin, in this case, extracts part of the oxygen from the iron, and renders it soluble in dilute acids.

III.—*Fruit and Wine Stains.*

These are best removed by a watery solution of the oxygenized muriatic acid (see chap. xiv. sect. 3,) or by that of oxygenized muriate of potash or lime, to which a little sulphuric acid has been added. The stained spot may be steeped in one of these solutions till it is discharged; but the solution can only be applied with safety to white goods, because the uncombined oxygenized acid discharges all printed and dyed colours. A convenient mode of

applying the oxygenized acid, easily practicable by persons who have not the apparatus for saturating water with the gas, is as follows : Put about a table-spoonful of muriatic acid (spirit of salt) into a tea-cup, and add to it about a tea-spoonful of powdered manganese. Then set this cup in a larger one filled with hot water. Moisten the stained spot with water, and expose it to the fumes that arise from the tea-cup. If the exposure be continued a sufficient length of time, the stain will disappear.

Stains on silk may be removed by a watery solution of sulphurous acid, or by the fumes of burning sulphur.

IV.—*Spots of Grease*

May be removed by a diluted solution of pure potash ; but this must be cautiously applied, to prevent injury to the cloth. Stains of *white wax*, which sometimes fall upon the clothes from wax candles, are removeable by spirit of turpentine or sulphuric ether. —The marks of *white paint* may also be discharged by the last-mentioned agents.

APPENDIX I.

OF THE RECENT DISCOVERIES IN CHEMISTRY.

SINCE this work was committed to the press, several new facts have been discovered, the importance of which requires that they should be noticed, though published too late to be inserted in their proper place. Of these the principal part are contained in Mr. Davy's last communication to the Royal Society, a copy of of which he has been so obliging as to transmit to me, previously to its publication in the Philosophical Transactions.* These discoveries lead to some changes in the views, which have been given in the first volume, of the nature of certain chemical agents. In researches, indeed, so refined and complicated, and involving so many sources of error, it is to be expected that frequent changes will be required, both in the enunciation of facts, and in the conclusions deduced from them.

I.—*On Ammonia—Its Formation from Charcoal and Pearlash—Presence of Oxygen in it—Amalgam of Mercury and Ammonium.*

From the researches of Mr. Davy, of which an outline has been given at page 194 vol. i. it appeared to follow that, by the action of potassium on ammonia, the nitrogen which enters into the constitution of that alkali, suffers a decomposition, since a less quantity of nitrogen gas is obtained by the agency of this metal than by electrical analysis. At the same time the increased production of hydrogen gas pointed out hydrogen as a probable element of nitrogen. MM. Gay Lussac and Thenard, however, have asserted that the fusible substance, generated by heating potassium in ammonia, may be made to give out the whole of the ammonia which has been absorbed by the process, two fifths as ammonia, one fifth as hydrogen and nitrogen ; and the remaining two fifths, by the addition of water, in the form of volatile alkali. They agree with Mr. Davy as to the evolution of hydrogen ; but maintain that as all the ammonia is recovered, the hydrogen gas must be furnished by the decomposition of potassium.

These discordant results have led Mr. Davy to repeat his former experiments, with the observance of every possible precau-

* Part I. for 1810.

tion. The fusible substance was formed by heating potassium on a tray of platina, which was placed in ammoniacal gas, contained in a retort of glass free from metallic oxides. A tube of solid platina was employed for distilling the fusible substance, which had thus been formed ; and the greatest care was employed to prevent the admission of moisture. Under these circumstances, not more than one tenth of the ammonia, which had been absorbed, was recovered. Potassium was regenerated : but so far from having an increased product of hydrogen, *both* the gases constituting ammonia fell short of their due proportion ; and the loss of hydrogen was found to be even greater than that of nitrogen. In these more refined experiments, then, the potassium is recovered ; but neither the ammonia nor its elements, unless a new body be added, which is capable of furnishing both oxygen and hydrogen.

Similar results were obtained by substituting sodium for potassium. Still less ammonia was separated from the fusible substance ; and the evolved gases, instead of bearing to each other the proportions obtained by electrical analysis, (*viz.* about three of hydrogen and one nitrogen,) consisted of two parts of hydrogen to one of nitrogen. The nitrogen, in this case, so far from being deficient, was in considerable excess. Mr. Davy, therefore, draws the conclusion, that Gay Lussac and Thenard were misled by the introduction of moisture.

The production of ammonia, which has been observed by Dr. Woodhouse to take place, on adding water to a mixture of pearlash and charcoal that has been ignited, is connected (it appears probable from Mr. Davy's recent experiments) with the absorption of nitrogen from the atmosphere. After a number of operations on the same materials the ammonia ceases to be produced. In comparative trials, also, more ammonia was generated from a mixture cooled in contact with the external air, than from one which had been cooled in contact with the gas generated in the experiment.

The important question, respecting the presence of oxygen in ammonia, has again occupied a share of Mr. Davy's attention. If oxygen exist as an element of that alkali, why, it may be asked, is it not found in the results of its electrical analysis ? It ought to be discovered in them, either in the state of oxygen gas ; or united with hydrogen in the state of aqueous vapour ; or combined with the metallic conductors. The two first methods of accounting

for it are not confirmed, either by Mr. Davy's experiments or by my own; for, in our former researches, we could neither of us detect oxygen gas, nor any increased quantity of water. It might, however, be alleged that the volume of ammonia being doubled by electricity, the evolved gases may hold more water than the original alkaline gas. In his recent experiments, therefore, Mr. Davy contrived to keep the volume of gas exactly the same during the whole time of decomposition; with the expectation that any water, which might be formed, would then be apparent. But though eight cubical inches of ammonia were decomposed, the indications of moisture were so indistinct, as to be extremely equivocal. The wires, however, were uniformly tarnished; but this might possibly arise either from the decomposition of a small quantity of water present in the alkaline gas, or from the action of the alkali itself on the metal.

Another method of determining this important question is by an accurate comparison between the weight of the ammonia submitted to experiment, and the weight of the gases resulting from its decomposition. For it must be evident that the weight of the latter (if oxygen be not an element of ammonia,) ought precisely to equal that of the former. In order to determine this point, Mr. Davy again tried, with great caution, the relative specific gravities of nitrogen, hydrogen, and ammonia at 30.5 barometer, and 51° of Fahrenheit's thermometer; and found them to be as follows.

		Grains.
For nitrogen gas, 100 cubic inches,		29.8
For hydrogen,	ditto,	2.27
For ammonia,	ditto,	18.4

Calculating, therefore, on these data, and assuming that 185 of permanent gas result from 100 of ammonia, there is a loss of $\frac{1}{12}$th. On the whole, however, the idea, that ammonia is decomposed into hydrogen and nitrogen alone, by electricity, and that the loss of weight is no more than is to be expected in processes of so delicate a kind, is, in Mr. Davy's opinion, the most defensible view of the subject.

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The nature of the amalgam from ammonia is rendered extremely uncertain by these experiments; nor have Mr. Davy's later attempts to obtain ammonium in a separate state been at all more successful than his former ones. One great difficulty consists in procuring the amalgam free from water, of which it always con-

tains sufficient to furnish oxygen, and to regenerate the alkali. The amalgam which appears to be most free from adhering moisture, is that of potassium, mercury, and ammonium in a solid state ; but even this amalgam gave on distillation only hydrogen gas, besides a small proportion of ammonia. The estimate of the quantity of matter added to the mercury in the formation of the amalgam, Mr. Davy has increased from about $\frac{1}{12000}$th to $\frac{1}{1600}$th. On the phlogistic or French view of the phenomena, it would be about $\frac{1}{900}$th.

II.—*Nature of Nitrogen, Hydrogen, &c.*

One of the principal facts, that suggested the compound nature of nitrogen (*viz.* the action of potassium on ammonia,) it has already been stated, fails, on farther examination, to support this inference. Neither does it appear that any of the phenomena, which have been considered as leading to the same conclusion, have been determined with the necessary degree of precision.

One of the most striking cases, in which nitrogen has been supposed to appear, without the presence of any other matter but water that can be conceived to supply its elements, is in the decomposition and recomposition of water by electricity. In the experiments of Dr. Pearson, with whatever care the water had been deprived of air by long boiling and the air-pump, there was always found, in the results of its analysis, a proportion of nitrogen gas. The same event followed, in the recent repetition of these experiments by Mr. Davy. By a careful scrutiny, however, of every possible source of error attending the combustion of the two gases, it was at length discovered, that at the moment of explosion by the electrical discharge, a communication was opened with the atmosphere, through the apertures into which the wires were hermetically sealed. When this source of fallacy was avoided by a proper modification of the apparatus, the gases evolved turned out to be pure oxygen and hydrogen only, without any admixture of nitrogen. These two gases, indeed, are alone produced by the Voltaic electrization of water, when the circumstances are quite unobjectionable ; and the water, after the experiment, exhibits no trace either of acid or alkali.

Sources of fallacy, of a different kind but of equal amount, in processes supposed to show the formation of nitrogen, were discovered in the generation of nitric acid from the steam of water passed over ignited manganese—in the production of ammonia on adding water to a mixture of charcoal and potash that had been

ignited—and in the apparent generation of nitrogen from congeal-
ed water. The attempts, therefore, to prove synthetically the
composition of nitrogen, may be considered, without exception, as
having proved abortive.

Nor have the experiments, directed to the decomposition of this
basis, been followed by any better success. Potassium was ignit-
ed, by intense Voltaic electricity, in nitrogen gas. In all trials of
this kind, hydrogen gas was produced, and nitrogen was found de-
ficient. This, at first, seemed to lead to the inference that nitro-
gen had been decomposed in the process. But Mr. Davy after-
wards found, that in proportion as the potassium was introduced
more free from a crust of potash, which would furnish water and
consequently hydrogen in the experiment, so, in proportion, was
there less of this gas evolved. The slight loss of nitrogen, there-
fore, is probably owing to its combination with nascent hydrogen ;
and the general tenour of these inquiries lends, it appears, no
strength to the suggestion, formerly thrown out by Mr. Davy, that
nitrogen is decomposed by distilling, in iron tubes, the olive col-
oured substance obtained from potassium and ammonia.

Reasoning on the proportions of hydrogen and ammonia obtain-
ed by distilling the singular amalgam of mercury and that alkali,
Mr. Davy infers that ammonia (supposing it to be an oxide) must
contain about 48 *per cent.* of oxygen. And, if hydrogen be sup-
posed to be a simple body, and nitrogen an oxide, then, on the
same hypothesis, nitrogen would consist of nearly 48 oxygen and
43 basis. But if we adopt the opinion that hydrogen and nitrogen
are both oxides of the same metal, then the quantity of oxygen in
nitrogen must be supposed less.

That nitrogen is not a metal in the form of gas, Mr. Davy
thinks is almost demonstrated by the nature of the fusible sub-
stance from ammonia ; besides that the general analogies of chem-
istry would lead to the notion of its being compounded. Should
it, he observes, be established by future researches, that hydrogen
is a protoxide of ammonium ; ammonia a deutoxide ; and nitro-
gen a tritoxide of the same metal, the theory of chemistry would
attain a happy simplicity ; and the existing arrangements would
harmonize with all the new facts.

III.—*Nature of Potassium and Sodium.*

In generalizing the facts, which formed the subject of Mr. Da-
vy's " Lecture on the Decomposition of the Fixed Alkalis,"[*] that
                * Philosophical Transactions, 1808

illustrious philosopher was fully aware, that the phenomena admitted of two different views ; and that they might be explained on principles directly opposed to each other. For we may either consider the new metals as simple substances, and the fixed alkalis as compounds of these elementary bodies with oxygen ; or it may be argued that the new metals are compounds of certain unknown bases with hydrogen, and the alkalis compounds of the same bases with water. It is the former of these hypotheses which Mr. Davy has been, from the first, disposed to adopt as being more simple ; more fully adequate to the explanation of phenomena ; and requiring the supposition of fewer unknown principles. In France, however, and by a few philosophers of our own country, the opposite hypothesis has been preferred, and has been supported chiefly by the following arguments.*

1. We have no other example, it is alleged, in which a metallic oxide is of greater specific gravity than its parent metal ; whereas, admitting Mr. Davy's explanation, this would be true of the oxides of potassium and sodium. Does not (it has been asked) the greater levity of the new metals rather indicate, that they are compounds of the alkalis with the most highly attenuated species of matter hitherto discovered, *viz.* hydrogen ?

To this argument Mr. Davy has replied that the fact may be equally well explained on either hypothesis. The density of a compound, he observes, will be proportional to the attraction of its parts. Potassium, in consequence of its strong affinity for oxygen, condenses it to a great degree ; while platina, which has a weak affinity for the same base, occasions very little condensation of it. Sulphuric acid is lighter than sulphur ; but phosphoric acid, in which there is a strong affinity between the base and oxygen, is heavier than phosphorus. Again the oxide of tin (wood tin) is very little inferior to tin in specific gravity. In this instance, the metallic base is comparatively light, and the attraction for oxygen strong ; and in a case where the metal is much lighter and the attraction for oxygen stronger, it might be expected *a priori* that the oxide would be heavier than the base.

Besides, the argument would prove too much. For since sodium absorbs much more oxygen than potassium, it ought, on the hypothesis of hydrogenation, to contain much more hydrogen ; yet though soda is said to be lighter than potash (in the proportion of

* See *Memoires d' Arcueil,* ii. ; Sylvester's Elementary Treatise of Chemistry, page 123.

13 to 17 nearly,) yet sodium is heavier than potassium in the proportion of 9 to 7 at least.

2. In the production of the new metals from potash and soda by galvanic electricity, we can never, it is argued, employ the alkalis in a state of complete dryness. In the most highly dephlegmated potash, at least 13.89 *per cent.* of water have been discovered, and soda, from the recent experiments of M. Berard, appears to contain 18.86 *per cent.** Now it is contended, and not without reason, that this large proportion of water cannot fail greatly to influence the phenomena. Oxygen gas is evolved in abundance at the positive pole; but we have no evidence that hydrogen gas appears (as might be expected) at the negative pole, along with the new metal. This argument seems to me the strongest that has yet been advanced in favour of the phlogistic theory; and to demand for its refutation an appeal to fresh experiments. It may be remarked, however, that the phenomena attending the production of potassium from potash and ignited iron (vol. i. page 264) are less favourable to the theory of hydrogenation. In this process it would rather appear, that both the alkali and the water are deprived of oxygen; and that the hydrogen of the latter forms no new combination, except that of potassuretted hydrogen gas, which comes over in torrents.

3. When the alkalis are regenerated from potassium and sodium, either by the action of oxygen gas, of water, or of muriatic acid, the effect, which Mr. Davy ascribes simply to the oxidizement of the metals, is imputed by others to the union of the absorbed oxygen with hydrogen existing in those bodies as an element. On the latter supposition water must be generated; and this, uniting with the alkaline base, (the other ingredient of the metal,) must form a hydrate of potash or soda. Now it has been determined experimentally that the same quantity of hydrogen gas is separated by a given weight of potassium, whether the metal be made to act on water or on muriatic acid; and this has been urged as a proof that the hydrogen proceeds from the metal.† The fact, however, may be equally well explained by referring the hydrogen gas, in both cases, to the decomposition of water.

When potassium or sodium is burned in oxygen gas, no person

* *Annales de Chimie,* lxii, 96; or according to Darcet 28 *per cent. Annales de Chimie,* lxviii.

† M. Berard has remarked (*Annales de Chimie,* lxxi. 64) that the greater proportion of water in soda than in potash confirms the notion that sodium contains more hydrogen than potassium.

has yet attempted to show that water appears in a separate state, and, if any be formed, it must therefore be looked for in the alkali which is generated. Potassium burned in oxygen gas, that has been dried by ignited potash, absorbs oxygen in the proportion of about $\frac{11}{20}$ths of a cubic inch for every grain of the metal consumed; and when sodium is consumed in a similar manner, about a cubical inch is taken up by every grain of metal. The alkalis, thus form-ed, are only imperfectly fusible at a red-heat, and do not, like the easily fusible alkalis, give indications of the presence of moisture. To substantiate, however, the total absence of hydrogen from the metals, it would be necessary to prove more distinctly that the alkalis, which are generated by their combustion, are *absolutely free* from water.

Potash, after being kept for some time in a state of fusion, it has already been stated, contains nearly 14 *per cent.* of water, the whole of which it abandons when the alkali enters into union with muriatic acid. Now muriate of potash, formed by the combustion of potassium in muriatic acid gas, ought, if no water were gener-ated, to be in a state of absolute dryness. From two experiments on the combustion of potassium in muriatic acid gas, performed with great care, Mr. Davy has shown that this is actually the case, and that the potash, thus formed, contains fully nine *per cent.* less water even than that assumed by Mr. Berthollet as a standard.

4. The last fact, urged in proof of the compound nature of the new metals, has been already quoted on the authority of Gay Lussac and Thenard, who acknowledge that it is the only one which is not equally well explained on either hypothesis.[*] Hydro-gen gas, they contend, is formed by the action of potassium on ammonia, even though the whole of the ammonia or of its elements may be recovered. Hence they apprehend it is evident that the new metals are *hydrurets*, or compounds of hydrogen with a pe-culiar base. The experiments, however, on which this inference rests, have been satisfactorily shown by Mr. Davy (as stated in the first section of this Appendix) to involve sources of fallacy suffi-cient to render it extremely questionable. The argument, in-deed, appears to me to have less weight than some of the others which have been already advanced.

On the whole, the question respecting the elementary or com-pound nature of the new metals cannot be considered as decided; and will require, for its determination, experiments of the most refined and delicate kind. In the mean time, the probabilities ap-

[*] *Memoires d'Arcueil,* ii. 308.

pear to me to be in favour of that hypothesis, which supposes the new metals to be simple bodies, and the alkalis and earths to be oxides of these metals.

IV.—*Compounds of Tellurium and other Metals with Hydrogen.*

Some curious facts, originally described by M. Ritter, have been lately farther investigated by Mr. Davy, respecting the action of tellurium on water, and the formation of a singular compound of that metal with hydrogen. When any other oxidable metal is made to transmit galvanic electricity through water, hydrogen gas is extricated at the negative wire. But when tellurium is made the negative surface, no hydrogen is evolved by it; but a purple fluid separates, which soon deposites a brown powder. The purple fluid, Mr. Davy finds, is a watery solution of a compound of tellurium and hydrogen. This compound gradually loses a part of its hydrogen, and becomes a solid hydruret of tellurium. When wholly uncombined, it is gaseous at common temperatures; and when muriatic or sulphuric acid is added to the water in which it is produced, it is not dissolved, but is given off, and may be collected and examined.

When potash was acted upon by means of a surface of tellurium negatively electrified, there was a most violent action. Potassium was separated as in other cases, and combined with the tellurium, forming a peculiar alloy. When this alloy was thrown into water, the potassium was oxidized, and the hydrogen of the water united with the tellurium, composing telluretted hydrogen, which formed, with the potash, a peculiar compound soluble in water. On adding a little diluted muriatic acid to the mixture, it effervesced violently, and gave a smell very like that of sulphuretted hydrogen.

The alloy of tellurium and potassium, Mr. Davy finds, may be prepared by submitting to heat the oxide of tellurium and potash mixed with powdered charcoal. In this case the affinity of the metals for each other is opposed to their affinities for oxygen.

The aëriform compound of tellurium and hydrogen or *telluretted hydrogen gas* is more analogous to sulphuretted hydrogen than to any other body. The smell of the two gases is almost precisely the same. Its aqueous solution is of a claret colour, but soon becomes brown, and deposites tellurium by exposure to the air. When disengaged from an alkaline solution by muriatic acid, it reddens moistened litmus; but, after being washed in a small quantity of water, it loses this property. In the latter case,

however, it is partially decomposed by the air in the water, so that it is not easy to say whether the power is inherent in it, or depends on the diffusion of a small quantity of muriatic acid through it. In other respects, it resembles a weak acid, combining with water and the alkalis. It precipitates most metallic solutions. It is instantly decomposed by oxy-muriatic acid, depositing a film at first metallic, but which is soon converted into muriate of tellurium.

The phenomena produced by substituting ARSENIC for tellurium in similar experiments were considerably different. Arsenic, made the negative surface in water, became dark coloured and threw down a brown powder, but it likewise gave off a considerable quantity of hydrogen gas. Negatively electrified in contact with solid potash, an alloy of potassium and arsenic was formed of a dark grey colour and perfectly metallic, which gave off arsenuretted hydrogen by the action of water. Potassium and arsenic, simply heated together, combined with such violence as to exhibit an actual inflammation, and yielded a similar alloy.

By heating these alloys of tellurium and arsenic with potassium in ammoniacal gas, an elastic fluid was generated, which consisted of four sixths nitrogen, instead of being pure hydrogen, as in the action of potassium alone. If it be said, then, that the metal and not the ammonia is decomposed in processes of this kind, it must be considered (Mr. Davy argues) in some cases as a compound of nitrogen, and in others as a compound of hydrogen, which are contradictory assumptions.

V.—*Nature of Sulphur, Phosphorus, and their Combinations with Hydrogen.*

From the experiments of Mr. Davy, of which an abstract is given in the first volume, it appeared extremely probable that both sulphur and phosphorus contain hydrogen. The intense ignition, which these bodies exhibit during their combination with potassium, led him also to suspect that they might contain oxygen; but this inference has since been rendered questionable by the fact, that similar phenomena attend the action of potassium on tellurium and arsenic. Neither is the diminution of the power of potassium to decompose water, after its union with sulphur and phosphorus, so clearly established, as to furnish proof of the presence of oxygen in these bodies. The idea, however, is still supported by several analogies, and especially by their property of being non-conductors of electricity.

Sulphuretted hydrogen gas, Mr. Davy states to weigh 35 grains for 100 cubical inches; and as the gas contains a volume of hydrogen gas precisely equal to its own, it will consist of 2.27 hydrogen, and 32.73 sulphur; and hence 100 parts by weight will contain

> 93.51 sulphur
> 6.49 hydrogen
> ———
> 100

When sulphuretted hydrogen is decomposed by common electricity, there is a slight diminution of volume, and the precipitated sulphur appears to contain a little hydrogen; but when Voltaic sparks are transmitted through it, the sulphur is precipitated in its common form, and there is no change of volume.

Arsenuretted and phosphuretted hydrogen gases are also decomposed by electricity without changing their bulk. But neither arsenic nor phosphorus are separated in their ordinary states. The phosphorus has a dark colour, and the arsenic is a brown powder; and both substances probably contain hydrogen. If potassium be brought into contact with these gases in smaller quantity than is necessary to decompose the whole, there is always an expansion of volume. Both gases, therefore, must contain more than their own volume of hydrogen, probably half as much more or twice as much more. From experiments on the weight of these gases, Mr. Davy finds that 100 cubic inches of arsenuretted hydrogen weigh about 15 grains, and 100 cubic inches of phosphuretted hydrogen about 10 grains. Mr. Dalton, however, from recent experiments, is disposed to consider phosphuretted hydrogen as much heavier; and to rate the 100 cubical inches at 26 grains.

VI.—*Of Mr. Dalton's New System of Chemical Elements.*

I have already (vol. i. page 60) stated very briefly the principle on which Mr. Dalton has founded his new system of chemical elements, or what may be called the *atomic system.* Into the details of this theory, or the analogies on which it rests, I have purposely, however, foreborn to enter; because nothing more than a brief outline has hitherto been laid before the public by the author himself. In the second part of his " New System of Chemical Philosophy," which is nearly ready for publication, not only the facts, many of which have been obtained by his own elaborate researches, but the train of reasoning to which they have led, will be fully developed. In the mean time I subjoin, from the first part of

Mr. Dalton's work, the table of the relative weights of several bodies, with some corrections, resulting from his late experience, which he has been so obliging as to communicate to me. To explain the method in which these numbers have been deduced, it may be proper to add the following remarks.

Let us suppose that any two elementary bodies a and b form a binary compound, and that they have been proved experimentally to unite in the proportion by weight of 5 of the former to 4 of the latter; then, since according to the hypothesis, they unite particle to particle, these numbers will express the relative weights of their atoms. But besides combining atom to atom singly, one atom of a may also combine with 2 of b or with 3, 4, &c. Or, reversely, 1 of b may unite with 2 of a or with 3, 4, &c. When such a series of compounds exists, the relative proportion of their elements ought necessarily, on analysis, to be proved to be 5 of a to 4 of b; or 5 to $(4 + 4 =)8$; or 5 to $(4 + 4 + 4 =) 12$; &c.; or, contrariwise, 4 of b to 5 of a, or 4 to $(5 + 5 =) 10$; or 4 to $(5 + 5 + 5 =) 15$. Between these, there ought to be no intermediate compounds; and the existence of any such would be fatal to the hypothesis.

To verify these numbers, it may be proper to examine the combinations of a and b with some third substance, for example with c. Let us suppose that in the binary compound of a and c, analysis discovers 5 parts of the former and 3 of the latter. Then, if c and b are also capable of forming a binary compound, their relative proportions by weight in this compound ought to be 4 of b to 3 of c, since these numbers denote the relative weight of their atoms. Now this is precisely the method, by which Mr. Dalton has deduced and verified the relative weights of oxygen, hydrogen, and nitrogen; the two first from the known composition of water; and the two last from the proportion of the elements of ammonia. Extending the comparison to a number of other bodies, he has obtained a scale of the relative weights of their atoms.

The hypothesis, therefore, although its leading principle be a gratuitous assumption, must stand or fall by the results of analysis. The instances in which it agrees with these results, are already very numerous; and none have hitherto been shown to be directly contradictory to it. If it should continue to derive support from the progress of discovery, its importance will be scarcely less felt in assisting and directing future investigations, than in determining the accuracy of our present knowledge.

Relative weights of the ultimate atoms of several bodies.

Hydrogen	-	1	Potassium	-	43
Nitrogen	-	5	Strontites	-	46
Carbon	-	5	Barytes	-	68
Oxygen	-	7	Iron	-	50
Phosphorus	-	9	Zinc	-	56
Sulphur	-	13	Copper	-	56
Magnesia	-	17	Lead	-	95
Lime	-	24	Silver	-	100
Soda	-	28	Platina	-	100
Sodium	-	29	Gold	-	140
Potash	-	42	Mercury	-	167

BINARY COMPOUNDS.

An atom of WATER or STEAM, composed of one oxygen and one hydrogen, retained in physical contact by a strong affinity ; and supposed to be surrounded by a common atmosphere of heat - - - - - - - - 8

An atom of AMMONIA, composed of one atom of nitrogen and one atom of hydrogen - - - - - - 6

An atom of NITROUS GAS composed of one atom of nitrogen and one of oxygen - - - - - - 12

An atom of OLEFIANT GAS composed of one atom of carbon and one of hydrogen - - - - - - 6

An atom of CARBONIC OXIDE composed of one atom of carbon and one of oxygen - - - - - - 12

An atom of SULPHURETTED HYDROGEN composed of one atom of sulphur and one of hydrogen - - - - 14

TERNARY COMPOUNDS.

An atom of NITROUS OXIDE two nitrogen and one oxygen - - - - - - - - - - 17

An atom of NITRIC ACID one nitrogen and two oxygen - - - - - - - - - 19

An atom of CARBONIC ACID one carbon and two oxygen - - - - - - - - - 19

An atom of CARBURETTED HYDROGEN one carbon and two hydrogen - - - - - - - - 7

QUATERNARY COMPOUNDS.

OXY-NITRIC ACID. One atom of nitrogen + three oxygen - - - - - - - - - 26

SULPHURIC ACID. One sulphur + three oxygen - 34

ALCOHOL. Three carbon + one hydrogen - - 16

NITROUS ACID. One nitric acid + one nitrous gas - 31

ACETIC ACID. Two carbon + two water - - 26

NITRATE OF AMMONIA. One nitric acid + one ammonia
+ one water - - - - - - - - - 33

SUGAR. One alcohol + one carbonic acid - - 35

VII.—*Proportion of the Elements of some Combinations.*

The precise determination of the composition of neutral and other salts is of the greatest importance, not only for the facts themselves, but still more for their application in almost every species of analysis, and their influence on the general doctrines of chemistry. On this subject Berthier has lately contributed some new experiments ;* and Berard has published a valuable memoir. The muriates of barytes and silver have been examined by the former, and found to be composed as follows.

Muriate of barytes in crystals consists of

Base - - - - 64
Acid - - - - 21
Water - - - - 15
—————
100

Deprived of water, the same salt is composed of

Base - - - - 75.3
Acid - - - - 24.7
—————
100

The muriate of silver consists of

Acid - - - - 18.3
Silver - - - - 75
Oxygen - - - 6.7
—————
100

This determination agrees very nearly with Gay Lussac's latest experiment, quoted by Berard, *viz.*

Acid - - - - 18.03
Base - - - - 81.97
—————
100

M. Berard's researches† were directed chiefly to the analysis of the alkaline carbonates and sub-carbonates ; but several other salts were examined in the course of the inquiry.

The saturated carbonates of potash and soda were formed by mingling the solutions of their sub-carbonates with one of sub-

* Nicholson's Journal, xxiv; 384. † Annales de Chimie, lxxi. 41.

carbonate of ammonia. The sub-carbonates of the same alkalis were formed by fusing their carbonates, a process which always affords them in an uniform state as to the proportion of their elements. The sub-carbonate of soda, it has been long known, may be obtained in crystals ; and Berard confirms the fact that sub-carbonate of potash is also capable of assuming a regular form. To obtain it in this state, supertartrate of potash is to be calcined, lixiviated, and the solution evaporated to the degree necessary for forming crystals, which are to be dried by blotting-paper. When these crystals are exposed to a sufficient degree of heat, they are entirely deprived of water; but retain their carbonic acid.

The following are the proportions of the ingredients in 100 grains of the crystallized salts.

	Acid.	Base.	Water.
Carbonate of potash	42.01	48.92	9.07
Sub-carbonate of ditto	23.83	56.17	20.0
Carbonate of soda	49.95	29.85	20.20
Sub-carbonate of ditto	13.98	23.33	62.69

Setting apart the water of crystallization, M. Berard has given the following table of the composition of neutral salts, deduced from his own experiments.

Salts.	Base.	Acid.	Total.
Muriate of potash	66.66	33.34	100
————— soda	57.00	43.00	100
Sulphate of barytes	67.70	32.30	100
————— potash	57.24	42.76	100
————— soda	47.22	52.78	100
Nitrate of potash	48.64	51.36	100
Carbonate of potash	53.81	46.19*	100
————— soda	44.38	55.62	100
Sub-carbonate of potash	70.21	29.79	100
————— soda	62.53	37.47	100

VIII.—*On the Combustion of different Kinds of Charcoal—the Proportions of Oxygen and Carbon in Carbonic Acid—and the Combustion of Hydrogen Gas.*

M. Saussure has lately published a memoir on this subject, which contains very ample and interesting details.[†] Its great length, however, will prevent me from giving more than a summary of the results of his experiments.

Plumbago, he found, when burned in oxygen gas, gives only

* Erroneously printed in the original 49.19.
† *Annales de Chimie,* lxxi. 254 ; Nicholson's Journal, xxvi. 161, 300.

carbonic acid and oxide of iron, without any mixture either of water or hydrogen gas. The products of this combustion establish that 100 grains of plumbago consist of 96 grains of carbon and four of iron; and that 100 grains of carbonic acid contain between 27.04 and 27.38 grains of carbon.

Next to plumbago, the purest kind of charcoal, which M. Saussure was able to procure, was that obtained by transmitting through a red-hot tube, the essential oil of rosemary. Its combustion afforded no water, and only a very minute quantity of carburetted hydrogen, too small in amount to affect the accuracy of the results. The composition of carbonic acid, deduced in this way, was 27.11 carbon and 72.89 oxygen.

The combustion of anthracite (glance-coal or stone-coal) and of charcoal of box-wood gave a product both of water and of carburetted hydrogen too considerable to allow much confidence to be placed in the results. The same substances were formed when charcoal was used, which had been employed in preparing the liquid sulphuretted hydrogen.* Hence it may be inferred that sulphur does not deprive charcoal of its hydrogen. M. Saussure is disposed to admit, with Mr. Davy, that sulphur contains both oxygen and hydrogen; the former of which, he supposes, unites with the hydrogen, while the latter combines with the carbon.

The conclusion, that oxygen gas sustains no change of volume by conversion into carbonic acid, is not impeached by these experiments. But when any of those varieties of charcoal were used, which contain hydrogen, a small increase of volume took place, if the hydrogen happened to escape unburned; and a diminution, if it was wholly consumed during the combustion.

In the course of his inquiries, M. Saussure had occasion to make some observations on several eudiometrical processes. Lime-water and even barytes water, he finds, are not adapted for removing small quantities of carbonic acid from oxygen gas; because the water of the solution acts on oxygen gas; of which it absorbs a small quantity abandoning at the same time a little nitrogen. A much better agent is the concentrated solution of potash, used over mercury, and in a quantity barely sufficient to effect the absorption.

The eudiometer of Volta, M. Saussure has found, in common with other chemists, not to be perfectly accurate. If the oxygen gas be in excess, the nitrogen which it contains, it is well known,

* See vol. i. page 267.

is apt to be condensed into nitric acid.* But it even appears, from M. Saussure's researches, that an excess of hydrogen does not insure precision; for, in this case, he has discovered that nitrate of ammonia is generated. The slow inflammation of hydrogen gas and of all the varieties of carburetted hydrogen in atmospheric air, is attended with a production of nitrate of ammonia.

Lastly, M. Saussure has added the important observation that all the varieties of hydrogen gas, even those which hitherto have been deemed quite pure, whether obtained by the solution of metals in dilute acids; by the decomposition of water by Voltaic electricity; or by passing ammonia through a red-hot tube, contain charcoal and probably even oxygen also, for they all yield carbonic acid when inflamed with an excess of oxygen gas. When there is a deficiency of oxygen, the carbon remains unconsumed; but in this case the residuary hydrogen contains a greater proportional quantity of charcoal. The purest hydrogen, that M. Saussure has been able to obtain, yielded, by combustion with a redundance of oxygen, a quantity of carbonic acid equal to three thousandths of its bulk.

IX.—On the Tenacity of Ductile Metals.

M. Guyton Morveau has lately made a series of experiments on the tenacity of metals, the results of which do not exactly accord with those which have been heretofore obtained. With regard to copper, platina, silver, gold, and iron, his experiments agree with the statement given by Dr. Thomson in his System of Chemistry; but with respect to other metals they differ considerably.

A wire of 0.787 of a line English in diameter of	Supported before it broke, lb. avoird. Decimal parts.
Iron	549 250
Copper	302.278
Platina	274.320
Silver	187.137
Gold	150.753
Zinc	109.540
Tin	34.630
Lead	27.621†

It has generally been stated that lead, by the process of flatting, contrary to other metals, sustains a diminution of specific gravity;

* Some good remarks on this subject by Berthollet, jun. may be consulted in Nicholson's Journal, xxv. 154.

† Annales de Chimie, lxxi. 189; or Nicholson's Journal, xxvi. 102.

and M. Morveau, on repeating the experiment, found it to be correct. But when the lead is prevented from escaping laterally, by stamping the metal in a very strong collar, its density was ascertained to be increased from 11.358 to 11 388.

M. Morveau has determined, also, that the purest distilled water exerts a speedy action on lead, even when the water is contained in glass vessels, so as to exclude all galvanic influence. This effect, he finds, is connected with the presence of air in water; that it ceases as soon as the water is no longer capable of furnishing air; and that it does not take place at all in water, which has been thoroughly purged of air by long boiling or by the air-pump. What is most singular, however, and would require farther experiment before it could be admitted, is, that the presence of any neutral salt, as the sulphates, nitrates, muriates, &c. even, for instance, 0.002 of sulphate of lime, is sufficient to obstruct this action both in open and covered vessels.

X.—*Properties of Nickel.*

A set of experiments on nickel have lately been made by Professor Tourte of Berlin,[*] in consequence of his having to prepare a needle of that metal for the Royal Mineralogical Cabinet.

The colour of nickel, he compares to that of silver of twelve deniers heated to redness. The metal takes a fine polish, and has then a lustre intermediate between that of steel and platina. When ignited, the colour is changed to that of antique bronze. The intensity of this colour increases every time the metal is heated, and a stain of oxide is left which is removed by nitric acid.— When ignited in oxygen gas, it burns and throws out sparks.

At $54\frac{1}{2}°$ Fahrenheit M. Tourte found the specific gravity of nickel slightly hammered 8.402, and thoroughly hammered 8.932. It is ductile and tenacious, and may be drawn into the slenderest wire. It cannot easily be soldered, on account of a crust of oxide which forms on its surface. Its power of conducting heat is superior to that of either zinc or copper, with both of which it was compared.

The magnetic property of nickel is very remarkable, and is retained after being alloyed with a minute quantity of arsenic. Oxidation, however, diminishes it, even when the metal is oxidized only to such a degree as to be slightly tarnished. Heating it red-hot, for six times in succession, destroyed also its magnetic power. Its polarity, M. Tourte considers as entirely acquired, and as never existing without the previous application of a magnet.

[*] Nicholson's Journal xxvi. 99; or *Annales de Chimie*, lxxi.

APPENDIX II.

CONSISTING OF VARIOUS USEFUL TABLES.

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No. I.
CORRESPONDENCE BETWEEN ENGLISH AND FOREIGN WEIGHTS AND MEASURES.

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I.—*English Weights and Measures.*

Troy Weight.

Pound.	Ounces.	Drams.	Scruples.	Grains.	Grammes.
1 =	12 =	96 =	288 =	5760 =	372.96
	1 =	8 =	24 =	480 =	31.08
		1 =	3 =	60 =	3.885
			1 =	20 =	1.295
				1 =	0.06475

Avoirdupois Weight.

Pound.	Ounces.	Drams.	Grains.	Grammes.
1 =	16 =	256 =	7000	= 453.25
	1 =	16 =	437.5	= 28.328
		1 =	27.34375	= 1.7705

Measures.

Gal.	Pints.	Ounces.	Drams.	Cub. Inches.	Litres.
1 =	8 =	128 =	1024 =	231	= 3.78515
	1 =	16 =	128 =	28.875	= 0.47398
		1 =	8 =	1.8047	= 0.02957
			1 =	0.2256	= 0.00396

N. B.—The English ale-gallon contains 282 cubical inches.

II.—*German.*

71 lbs. or grs. English troy, = 74 lbs. or grs. German apothecaries weight.

1 oz. Nuremberg, medic. weight, = 7 dr. 2. sc. 9 gr. English.
1 mark Cologne, = 7 oz. 2 dwt. 4 gr. English troy.

III.—*Dutch.*

1 lb. Dutch, = 1 lb. 3 oz. 16 dwt. 7 gr. English troy.
787½ lbs. Dutch, = 1038 lbs. English troy.

IV.—*Swedish Weights and Measures, used by Bergman and Scheele.*

The Swedish pound, which is divided like the English apothecary, or troy, pound, weighs 6556 grs. troy.

The kanne of pure water, according to Bergman, weighs 42250 Swedish grains, and occupies 100 Swedish cubical inches. Hence the kanne of pure water weighs 48088.719444 English troy grains, or is equal to 189.9413 English cubic inches; and the Swedish longitudinal inch is equal to 1.238435 English longitudinal inches.

From these data the following rules are deduced:

1. To reduce Swedish longitudinal inches to English, multiply by 1.2384, or divide by 0.80747.

2. To reduce Swedish to English cubical inches, multiply by 1.9, or divide by 0.5265.

3. To reduce the Swedish pound, ounce, dram, scruple, or grain, to the corresponding English troy denomination, multiply by 1.1382, or divide by .8786.

4. To reduce the Swedish kannes to English wine pints, multiply by .1520207, or divide by 6.57805.

5. To reduce Swedish kannes to English wine gallons, multiply by .82225 or divide by 1.216.

6. The lod, a weight sometimes used by Bergman, is the 32d part of the common Swedish pound of 16 oz. and the 24th part of the pound of 12 oz. Therefore to reduce it to the English troy pound, multiply by .03557, or divide by 28.1156.

V.—*Correspondence of English Weights and Measures with those used in France before the Revolution.*

§ I.—WEIGHTS.

The Paris pound, *poids de marc* of Charlemagne, contains 9216 Paris grains; it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 English troy grains.

The English troy pound of 12 ounces contains 5760 English troy grains, and is equal to 7021 Paris grains.

The English avoirdupois pound of 16 ounces contains 7000 English troy grains, and is equal to 8532.5 Paris grains.

To reduce Paris grains to English troy grains, divide by
To reduce English troy grains to Paris grains multiply by } 1.2189

To reduce Paris ounces to English troy, divide by
To reduce English troy ounces to Paris, multiply by } 1.015734

Or the conversion may be made by means of the following tables :

1.—*To reduce French to English Troy Weight.*

The Paris pound	= 7561	⎫
The ounce	= 472.5625	⎬ English troy grains.
The gros	= 59.0703	⎪
The grain	= .8204	⎭

2.—*To reduce English Troy to Paris Weight.*

The English troy pound of 12 ounces	= 7021.	⎫
The troy ounce	= 585.0833	⎪
The dram of 60 grains	= 73.1354	⎪
The penny-weight or denier of 24 grains	= 29.2541	⎬ Paris grains.
The scruple of 20 grains	= 24.3784	⎪
The grain	= 1.2189	⎭

3.—*To reduce English Avoirdupois to Paris Weight.*

The avoirdupois pound of 16 ounces, or, 7000 troy grains	= 8538.	⎫ Paris grs.
The ounce	= 533.6250	⎭

§. II.—LONG AND CUBICAL MEASURES.

To reduce Paris running feet, or inches, into English, multiply by	⎫ 1.065977
English running feet, or inches, into Paris, divide by	⎭
To reduce Paris cubic feet, or inches, to English, multiply by	⎫ 1.211278
English cubic feet, or inches, to Paris, divide by	⎭

Or by means of the following tables :

4.—*To reduce Paris Long Measure to English.*

The French toise	= 6.3945 English feet.	
The Paris royal foot of 12 inches	= 12.7977	⎫
The inch	= 1.0664	⎬ English inches.
The line, or 1-12th of an inch	= .0888	⎪
The 1-12th of a line	= .0074	⎭

5.—*To reduce English Long Measure to French.*

The English foot	= 11.2596	⎫
The inch	= .9383	⎪
The 1-8th of an inch	= .1173	⎬ Paris inches.
The 1-10th	= .0938	⎪
The 1-12th	= .0782	⎭

6.—*To reduce French Cube Measure to English.*

$$\left.\begin{array}{l}\text{The Paris cube} \\ \text{foot} \\ \text{The cubic inch}\end{array}\right\} \begin{array}{l} = 1.211278 \\ = .000700 \end{array} \left.\begin{array}{l}\text{English}\\ \text{cubical}\\ \text{feet, or}\end{array}\right\} \left\{\begin{array}{l} 2093.088384 \\ 1.211278 \end{array}\right\} \text{inches.}$$

7.—*To reduce English Cube Measure to French.* *

$$\left.\begin{array}{l}\text{The English cube foot, or } 1728 \\ \quad \text{cubical inches} \\ \text{The cubical inch} \\ \text{The cube tenth}\end{array}\right\} \begin{array}{l} = 1427.4864 \\ = .8260 \\ = .0008 \end{array} \left.\begin{array}{l}\text{French cubi-} \\ \text{cal inches.}\end{array}\right.$$

§ III.—MEASURE OF CAPACITY.

The Paris pint contains 58.145† English cubial inches, and the English wine pint contains 28.875 cubical inches; or, the Paris pint contains 2.0171082 English pints, and the English pint contains .49617 Paris pints; hence,

$$\left.\begin{array}{l}\text{To reduce the Paris pint to the English, multi-} \\ \quad \text{ply by } - \quad - \quad - \quad - \quad - \quad - \quad - \\ \text{To reduce the English pint to the Paris, divide by}\end{array}\right\} 2.0171082$$

The septier of Paris is 7736 French, or 9370.45 English, cubical inches; and the muid is 92832 French, or 112445.4 English, cubical inches.

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* To convert the weight of a French cubic foot, of any particular substance given in French grains, into the corresponding weight of an English cubic foot in English troy grains, multiply the French grains by 0.6773181, and the product is the number of English troy grains contained in an English cubic foot of the same substance.

† It is said by Belidor, *Archit. Hydraul.* to contain 31 oz. 64 grs. of water, which makes it 58.075 English inches; but, as there is considerable uncertainty in the determinations of the weight of the French cubical measure of water, owing to the uncertainty of the standards made use of, it is better to abide by Mr. Everard's measure, which was made by the Exchequer standards, and by the proportions of the English and French foot, as established by the French Academy and Royal Society.

According to Beaume, the Paris pint contains 32 French ounces of water, at the temperature of 54.5° of Fahrenheit; which would make it equal to 59.729 English cubical inches.

VI.—*Table, showing the Comparison between French and English Grains.* (Poid de Marc.)

French grs.=English grs.		English grs.=French grs.	
* 1	0.8203	1	1.2189
2	1.6407	2	2.4378
3	2.4611	3	3.6568
4	3.2815	4	4.8757
5	4.1019	5	6.0947
6	4.9223	6	7.3136
7	5.7427	7	8.5325
8	6.5631	8	9.7515
9	7.3835	9	10.9704
10	8.203	10	12.189
20	16.407	20	24.378
30	24.611	30	36.568
40	32.815	40	48.757
50	41.019	50	60.947
60	49.223	60	73.136
70	57.427	70	85.325
80	65.631	80	97.515
90	73.835	90	109.704
100	82.03	100	121.89
200	164.07	200	243.78
300	246.11	300	365.68
400	328.15	400	487.57
500	410.19	500	609.47
600	492.23	600	731.36
700	574.27	700	853.25
800	656.31	800	975.15
900	738.35	900	1097.04
1000	820.3	1000	1218.9
2000	1640.7	2000	2437.8
3000	2461.1	3000	3656.8
4000	3281.5	4000	4875.7
5000	4101.9	5000	6094.7
6000	4922.3	6000	7513.6
7000	5742.7	7000	8532.5
8000	6563.1	8000	9751.5
9000	7383.5	9000	10970.4
* 10,000	8203.0	10,000	12189.0

* *Per* Farey (Nicholson's Journal, xxii. 338,) 1 grain French = 0.8204 English; 10,000 ditto = 8204 ditto.

VII.—*Table, showing the Comparison between French and English Cubical Inches.*

Cubic Inches.			Cubic Inches.	
French = English.			**English = French.**	
1	1.2136		1	0.8239
2	2.4272		2	1.6479
3	3.6408		3	2.4719
4	4.8544		4	3.2958
5	6.0681		5	4.1198
6	7.2817		6	4.9438
7	8.4953		7	5.7677
8	9.7089		8	6.5917
9	10.9225		9	7.4157
10	12.136		10	8.239
20	24.272		20	16.479
30	36.408		30	24.719
40	48.544		40	32.958
50	60.681		50	41.198
60	72.817		60	49.438
70	84.953		70	57.677
80	97.089		80	65.917
90	109.225		90	74.157
100	121.36		100	82.39
200	242.72		200	164.79
300	364.08		300	247.19
400	485.44		400	329.58
500	606.81		500	411.98
600	728.17		600	494.38
700	849.53		700	576.77
800	970.89		800	659.17
900	1092.25		900	741.57
1000	1213.6		1000	823.9
2000	2427.2		2000	1647.9
3000	3640.8		3000	2471.9
4000	4854.4		4000	3295.8
5000	6068.1		5000	4119.8
6000	7281.7		6000	4943.8
7000	8495.3		7000	5767.7
8000	9708.9		8000	6591.7
9000	10922.5		9000	7415.7
10,000	12136.0		10,000	8239.0

VIII.—*New French Weights and Measures (calculated by Dr. Duncan, jun.)*

1.—*Measures of Length : the Metre being at 32°, and the Foot at 62°.*

		English Inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre	=	.03937						
Centimetre	=	.39371						
Decimetre	=	3.93710						
Metre	=	39.37100						
Decametre	=	393.71000	=	0	0	10	2	9.7
Hecatometre	=	3937.10000	=	0	0	109	1	1
Kilometre	=	39371.00000	=	0	4	213	1	10.2
Myriometre	=	393710.00000	=	6	1	156	0	6

2.—*Measures of Capacity.*

		Cubic Inches.		Tons.	Hogs.	Wine G.	Pints.
Millilitre	=	.06103					
Centilitre	=	.61028			*English.*		
Decilitre	=	6.10280					
Litre	=	61.02800	=	0	0	0.	2.1133
Decalitre	=	610.28000	=	0	0	2.	5.1352
Hecatolitre	=	6102.80000	=	0	0	26.419	
Kilolitre	=	61028.00000	=	1	0	12.19	
Myriolitre	=	610280.00000	=	10	1	58.9	

3.—*Measures of Weight.*

		English Grains.		Poun.	Oun.	Drus.
Milligramme	=	.0154				
Centigramme	=	.1544				
Decigramme	=	1.5444		*Avoirdupois.*		
Gramme	=	15.4440				
Decagramme	=	154.4402	=	0	0	5.65
Hecatogramme	=	1544.4023	=	0	3	8.5
Kilogramme	=	15444.0234	=	2	3	5
Myriogramme	=	154440.2344	=	22	1	2

IX.—*Reduction of the Ounce Measures used by Dr. Priestley to Cubical Inches.*

Ounce Measures.	French Cubical Inches.	English Cubical Inches.
1	1.567	1.898
2	3.134	3.796
3	4.701	5.694
4	6.268	7.592
5	7.835	9.490
6	9.402	11.388
7	10.969	13.286
8	12.536	15.184
9	14.103	17.082
10	15.670	18.980
20	31.340	37.960
30	47.010	56.940
40	62.680	75.920
50	78.350	94.900
60	94.020	113.880
70	109.690	132.860
80	125.360	151.840
90	141.030	170.820
100	156.700	189.800
1000	1,567.000	1898.000

X.—*Table, showing the absolute Weights and Specific Gravities of Gases, and the Quantity of each absorbed by Water.*

(Temperature 60° Fahrenheit, Barometer 30°.)

KIND OF GAS.	Weight of 100 Cubic Inches in Eng. Grs.	Specific Gravity Standard.			No. of Cubic Inches absorbed by 100 Inches of Water.	
		Water.	Air.			
Water		1000				
Atmospheric air	31.	1.2279	1000	S.K.		
Oxygen gas	34.	1.35	1103	K.	37.	H.
Ditto ditto	34.74	1.39	1127	D.		
Azotic gas	30.535	1.21	985	K.	1.53	H.
Ditto ditto	30.45	1.20	980	D.		
Hydrogen gas	2.613	0.1031	84	K.	1.61	H.
Ammonia	18.16	0.715	585	K.		
Ditto	18.	0.713	580	D.	47500.	D.
Hydro-carburet from stagnant water	20.66		666	Dal.	1.40	H.
Ditto from water over ignited charcoal	14.5		468	Cr.		
Ditto from alcohol	16.		516	Cr.		
Ditto from ether	20.		645	Cr.		
Ditto from coal	20.2		650	Dal.		
Phosphuretted hydrogen	26.		839	Dal.	2.14	H.
Sulphuretted ditto	34.286	1.36	1142	K.	108.	H.
Ditto ditto	38.17		1231	Th.		
Olefiant gas	28.18		905	Dei.	12.5	Dal.
Vapour of alcohol	65.*		2100	Dal.		
Ditto of ether	70.†		2250	Dal.		
Carbonic oxide	30.	1.185	967	Cr.	2.01	H.
Nitrous oxide	50.1	1.985	1615		86.	H.
Nitric oxide	37.	1.465	1193	K.	5.	H.
Ditto ditto	34.3	1.36	1105	D.		
Carbonic acid	46.5	1.84	1500	K.	108.	H.
Ditto ditto	45.5	1.802	1470	D.		
Muriatic acid	44.7?	1.765	1430	B.	51500.	T.
Ditto ditto	59.8		1929	K.		
Nitric acid	76.	3.	2425	D.		
Sulphurous	70.215	2.75	2240	K.	3300.	T.

B. Brison; Cr. Cruickshank; D. Davy; Dal. Dalton; Dei. Deiman; H. Henry; K. Kirwan; S. Shuckburgh; T. Thompson; Th. Thenard.

* Of temperature 190° Fahrenheit, and force = 30 inches of mercury.

† Of temperature 100° Fahrenheit, and force = 30 inches of mercury.

XI.—*Table of the Specific Gravities of various Simple and Compound Gases.*

(Gay Lussac, *Memoires d' Arcueil*, vol. ii. p. 252.)

GASES.	Densities determined by Experiment.		Densities, calculated from the Proportion of the Elements, and their Contraction of Volume.
Atmospheric air	1.00000	Biot and Arago.	
Oxygen gas	1.10359		
Nitrogen gas	0.96913		
Hydrogen gas	0.07321		
Carbonic acid	1.5196		
Ammonia	0.59669		0.59438 (1)
Muriatic acid	1.278	Biot and G. Lussac.	
Nitrous oxide	1.61414	Davy.	
	1.30293	Berthollet.	1.52092 (2)
Nitrous gas	1.0388	Berard.	1.03636 (3)
Sulphurous acid	2.2650	Kirwan.	
Carbonic oxide	0.9569	Cruickshank.	0.96782 (4)
Steam of water	0.6896	Trales.	0.625 (5)
Oxymuriatic acid	2.470	Thenard.	2.468 (6)

(1) Supposing the contraction of the elements to be one half their total volume.

(2) The contraction of the elements being supposed equal to the whole oxygen gas.

(3) The contraction being supposed equal to half the whole volume.

(4) Supposing that 100 carbonic acid produce 100 carbonic oxide ; and lose, at the same time, 50 oxygen.

(5) Supposing the contraction equal to the volume of the oxygen gas.

(6) Supposing the condensation to be half the total volume.

XII.—*Table of the Proportions of several Compounds, whose Elements are Gaseous.*

(Gay Lussac, *Mem. d' Arcueil,* vol. ii. p. 253.

SUBSTANCES.	Proportions in volume.		Proportions in weight.	
Mur. of ammonia	100 ammon. gas	100 mur. gas	base 38.35	acid 61.65
Neutral carbon. of ammonia	100 ditto	100 car. ac. gas	do. 28.19	do. 71.81
Sub-carbon. of do.	100 ditto	50 ditto	do. 43.98	do. 56.02
Fluobor. of do.	100 ditto	100 fluob. gas		
Sub-fluob. of do.	100 ditto	50 ditto		
Water	100 hyd. gas	50 oxygen gas	ox. 86.733	hyd. 13.267
Nitrous oxide	100 nitrogen gas	50 ditto	nit. 63.72	ox. 36.28
Nitrous gas	100 ditto	100 ditto	do. 46.757	do. 53.243
Nitric acid	100 ditto	200 ditto	do. 30.512	do. 69.488
Ditto ditto	200 nitrous gas	100 ditto	do. do.	do. do.
Nitrous acid gas	300 ditto	100 ditto	do. 34.507	do. 65.493
Ammonia	100 nitrogen gas	300 hyd. gas	do. 81.525	do. 18.475
Sulphuric acid	100 sulphs.ac.gas	50 oxygen gas	sulr. 42.016	do. 57.984
Sulphurous acid			do. 52.083	do. 47.917
Oxymur. acid gas	300 m. ac. gas	100 ditto	m. ac. 77.65	do. 22.35
100 carbon. acid	100 carb. ox. gas	50 ditto	carb.27.376	do. 72.624
100 ditto ditto		100 ditto	do. do.	do. do.
100 carbonic oxide	50 ox. gas		carb.42.99	do. 57.01

XIII.—*Rules for reducing the Volume of Gases to a mean height of the Barometer, and mean Temperature.*

1. *From the space occupied by any quantity of gas under an observed degree of pressure, to infer what its volume would be under the mean height of the barometer, taking this at 30 inches, as is now most usual.*

This is done by the rule of proportion ; for, as the mean height is to the observed height, so is the observed volume to the volume required. For example, if we wish to know what space would be filled, under a pressure of 30 inches of mercury, by a quantity of gas, which fills 100 inches, when the barometer is at 29 inches,

30 : 29 : : 100 : 96.66.

The 100 inches would, therefore, be reduced to 96.66.

2. *To estimate what would be the volume of a portion of gas, if brought to the temperature of 60° Fahrenheit.*

Divide the whole quantity of gas by 480; the quotient will show the amount of its expansion or contraction by each degree of Fahrenheit's thermometer. Multiply this by the number of degrees which the gas exceeds, or falls below, 60°. If the temperature of the gas be above 60°, subtract, or if below 60°, add, the product to the absolute quantity of gas ; and the remainder in the first case, or sum in the second, will be the answer. Thus, to find what space 100 cubic inches of gas at 50° would occupy if raised to 60°, divide 100 by 480 ; the quotient 0.208 multiplied by 10 gives 2.08,

which added to 100, gives 102.08 the answer required. If the temperature had been 70°, and we had wished to know the volume, which the gas would have occupied at 60°, the same number 2.08 must have been subtracted from 100, and 97.92 would have been the answer.

3. In some cases, it is necessary to make a double correction, or *to bring the gas to a mean both of the barometer and thermometer.* We must then first correct the temperature, and afterwards the pressure. Thus to know what space 100 inches of gas at 70° Fahrenheit, and 29 inches barometer, would fill at 60° Fahrenheit and 30 inches barometer, we first reduce the 100 inches, by the second process, to 97.92. Then by the first

$$30 \quad : \quad 29 \quad : : \quad 97.92 \quad : \quad 94\ 63.$$

Or 100 inches, thus corrected, would be only 94.63.

4. *To ascertain what would be the absolute weight of a given volume of gas at a mean temperature, from the known weight of an equal volume at any other temperature ;* first, find by the second process what would be its bulk at a mean temperature ; and then say, as the corrected bulk is to the actual weight, so is the observed bulk to the number required. Thus if we have 100 cubic inches of gas weighing 50 grains at 50° Fahrenheit, if the temperature were raised to 60° they would expand to 102.08. And

$$102.08 \quad : \quad 50 \quad : : \quad 100 \quad : \quad 49.$$

Therefore 100 inches of the same gas at 60° would weigh 49 grains.

5. *To learn the absolute weight of a given volume of gas under a mean pressure, from its known weight under an observed pressure,* say, as the observed pressure is to the mean pressure, so is the observed weight to the corrected weight. For example, having 100 inches of gas which weigh 50 grains under a pressure of 29 inches, to know what 100 inches of the same gas would weigh, the barometer being 30 inches,

$$29 \quad : \quad 30 \quad : : \quad 50 \quad : \quad 51.72.$$

Then 100 inches of the same gas, under 30 inches pressure, would weigh 51.72 grains.

6. In some cases it is necessary to combine the two last calculations. Thus, if 100 inches of gas at 50° Fahrenheit, and under 29 inches pressure, weigh 50 grains, to find what would be the weight of 100 inches at 60° Fahrenheit, and under 30 inches of the barometer, first correct the temperature, which reduces the weight to 49 grains. Then,

$$29 \quad : \quad 30 \quad : : \quad 49 \quad : \quad 50.7.$$

One hundred inches, therefore, would weigh 50.7 grains.

XIV.—*Specific Gravities of Solid and Liquid Substances.*[*]

GEMS.	Specific Grav.	STONES, &c.	Specific Grav.
Diamond, white, oriental	3.5212	Jasper, brown	2.6911
Topaz, oriental	4.0106	Granite, Egyptian	2.6541
Sapphire, oriental	3.9941	Rock crystal	2.6530
Garnet, Bohemian	4.1888	Chalcedony, bright	2.6640
Beryl, oriental	3.5489	Carrara marble	2.7168
Hyacinth, common	3.6873	Alabaster, oriental	2.7302
Emerald, from Peru	2.7755	Carnelian	2.6137
Crysolithe, from Brazil	2.6923	Slate, common for roofs	2.8535
Amethyst, oriental	2.651	Flint	2.5941
Ruby, oriental	4.2833	Agate, oriental	2.5901
		Portland-stone	2.533
STONES, &c.		Serpentine, green, Italian	2.4295
Ponderous spar	4.4300	Opal, noble	2.144
Porphyry	2.7651	Pumice-stone	0.9145

SALTS.

	Hassen-fratz.	Kirwan.	Muschen-brock.	Newton.
Potash	1.7085	4.6215		
Lime	1.5233	2.3908	2.3700	
Magnesia	0.3460	2.3298		
Alumine	0.8200	2.0000		
Barytes	2.3740	4.0000		
Sulphate of potash	2.4073	2.636	2.398	
———— alumine	1.7109		1.7260	1.714
———— zinc	1.9120		1.9	1.712
———— iron	1.8399		1.88	
———— copper	2.1943	2.23		
Nitrate of potash	1.9369	1.933	1.901	1.900
Muriate of soda	2.2001		2.0835	2.143
Acetate of lead	2.3450		2.3953	
Super-tartrate of potash	1.9153		1.8745	
Sub-borate of soda	1.7230		1.7170	1.714
Carbonate of potash	2.0120		2.749	
———— soda	1.3591	1.421		
———— ammonia	0.9660	1.8245	1.5026	

GLASSES AND VITRIFICATIONS.	Specific Grav.	INFLAMMABLES.	Specific Grav.
Green bottle glass	2.7325	Roll-sulphur	1.9907
French crystal glass	2.8922	Phosphorus	1.714
French mirror-glass, from St.		Pit-coal	1.3292
Gobin	2.4882	Amber	1.0780
English flint-glass	3.3203	Heaviest charcoal	0.441
China porcelain	2.3847	Mineral naphtha	0.708
		Camphor	0.9887
		Liquid ammonia	0.8970

[*] For the specific gravities of the metals, see Table of the Qualities of Metals, near the close of this Appendix.

Table of Specific Gravities of Solid and Liquid Substances,—continued.

	Specific Grav.		Specific Grav.
WATERS.		**GUMS.**	
Distilled water	1.0000	Common gum	1.4817
Sea-water	1.0263	Gum Arabic	1.4523
Water from the Asphaltic Sea	1.2403	Gum tragacanth	1.3161
ACIDS.		**GUM-RESINS.**	
Sulphuric acid of commerce	1.8500	Asafœtida	1.3275
Sulphuric acid, real	2.1250	Scammonium, from Smyrna	1.2743
Nitric acid	1.5800	Galbanum	1.2120
Muriatic acid	1.1940		
Concentrated acetic acid	1.0626	**RESINS.**	
		Guaiacum	1.2289
SPIRITUOUS LIQUIDS.		Jalap	1.2185
Madeira wine	1.0382	Ammoniacum	1.2071
Cyder	1.0181	Benzoe	1.0924
Brown beer	1.0338	Sandarac	1.0920
Burgundy wine	0.9915	White resin	1.0819
Champaigne wine	0.962	Colophony	1.0441
Brandy	0.8371	Mastich	1.0742
Alcohol*	0.8293	Copal, transparent	1.0452
Nitric ether	0.9088	Elastic resin	0.9335
Acetic ether	0.8664		
Sulphuric ether†	0.7396	**INSPISSATED JUICES.**	
Muriatic ether	0.7296	Aloe *succotrina*	1.3795
		Opium	1.3366
ETHEREAL OILS.			
Oil of cinnamon	1.0439	**WOODS.**	
Oil of cloves	1.0363	Lignum guaiacum	1.3330
Oil of lavender	0.8938	Box wood, Dutch	1.3280
Spirit of turpentine	0.8697	French box wood	0.912
		Ebony	1.2090
		Heart of old oak	1.1700
FAT OILS.		Mahogany	1.063
Linseed oil	0.9403	Olive tree	0.9270
Poppy oil	0.9288	Mulberry tree, Spanish	0.8970
Oil of sweet almonds	0.9170	Beech tree	0.8520
Olive oil	0.9153	Yew tree, Spanish	0.8070
		Apple tree	0.7930
ANIMAL FLUIDS.		Plum tree	0.7850
Asses' milk	1.0355	Maple tree	0.7550
Cows' milk	1.0324	Cherry tree	0.7150
Human milk	1.0203	Quince tree	0.7050
Human urine	1.0106	Orange tree	0.7050
		Walnut tree	0.6710
ANIMAL FATS.		Pear tree	0.6610
Spermaceti	0.9433	Cypress, Spanish	0.6440
Butter	0.9423	Pine tree	0.5500
Tallow	0.9419	White Spanish poplar tree	0.5294
Mutton suet	0.9235	Cork	0.2400
Train oil	0.9235		
Hogs' lard	0.9568		
Ivory	1.825		
Bees' wax	0.9648		

* *Per* Chaussier 0.7980.   † *Per* Lovitz 0.6320.

XV.—*Rules for calculating the Absolute from the Specific Gravities of Bodies.*

In 1696, Mr. Everard, balance maker to the Exchequer, weighed before the commissioners of the House of Commons 2145.6 cubical inches, by the Exchequer standard foot, of distilled water, at the temperature of 55° of Fahrenheit, and found it to weigh 1131 oz. 14 dts. troy, of the Exchequer standard. The beam turned with 6 grs. when loaded with 30 pounds in each scale. Hence, supposing the pound avoirdupois to weigh 7000 grs. troy, a cubic foot of water weighs 62½ pounds avoirdupois or 1000 ounces avoirdupois, wanting 106 grains troy. And hence, if the specific gravity of water be called 1000, the proportional specific gravities of all other bodies will nearly express the number of avoirdupois ounces in a cubic foot. Or, more accurately, supposing the specific gravity of water expressed by 1, and of all other bodies in proportional numbers, as the cubic foot of water weighs, at the above temperature, exactly 437489.4 grains troy, and the cubic inch of water 253.175 grains, the absolute weight of a cubical foot or inch of any body in troy grains may be found by multiplying their specific gravity by either of the above numbers respectively.

By Everard's experiment, and the proportions of the English and French foot, as established by the Royal Society and French Academy of Sciences, the following numbers are ascertained :

Paris grains in a Paris cube foot of water	= 645511
English grains in a Paris cube foot of water	= 529922
Paris grains in an English cube foot of water	= 533247
English grains in an English cube foot of water	= 437489.4
English grains in an English cube inch of water	= 253.175
By an experiment of Picard with the measure and weight of the Chatelet, the Paris cube foot of water contains of Paris grains	= 641326
By one of Du Hamel, made with great care	= 641376
By Homberg	= 641666

These show some uncertainty in measure or in weights ; but the above computation from Everard's experiment may be relied on, because the comparison of the foot of England with that of France was made by the joint labour of the Royal Society of London and the French Academy of Sciences : it agrees likewise very nearly with the weight assigned by M. Lavoisier, 70 Paris pounds to the cubical foot of water.

XVI.—*Table for reducing the Degrees of Baume's Hydrometer to the Common Standard.*

Baume's Hydrometer for Liquids lighter than Water.
Temperature 55° Fahrenheit, or 10° Reaumur.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
10	1.000	18	.942	26	.892	34	.847
11	.990	19	.935	27	.886	35	.842
12	.985	20	.928	28	.880	36	.837
13	.977	21	.922	29	.874	37	.832
14	.970	22	.915	30	.867	38	.827
15	.963	23	.909	31	.871	39	.822
16	.955	24	.903	32	.856	40	.817
17	.949	25	.897	33	.852		

Baume's Hydrometer for Liquids heavier than Water.
Temperature 55° Fahrenheit, or 10° Reaumur.

Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.	Deg.	Sp. Gr.
0	1.000	21	1.170	42	1.414	63	1.779
3	1.020	24	1.200	45	1.455	66	1.848
6	1.040	27	1.230	48	1.500	69	1.920
9	1.064	30	1.261	51	1.547	72	2.000
12	1.089	33	1.295	54	1.594		
15	1.114	36	1.333	57	1.659		
18	1.140	39	1.373	60	1.717		

XVII.—*Table, showing the Specific Gravity of Mixtures of Alcohol and Water.*

Centesimal parts of the Mixture.	SPECIFIC GRAVITIES.	
	According to Chaussier.	According to Gilpin (last table.)
Alcohol . 100	0.7980	0.825
95	0.8165	0.83887
90	0.8340	0.85244
85	0.8485	0.86414
80	0.8620	0.87606
75	0.87525	0.88762
70	0.8880	0.89883
65	0.9005	0.90941
60	0.9120	0.91981
55	0.9230	0.92961
50	0.9334	0.93882
45	0.94265	0.94726
40	0.9514	0.95493
35	0.95865	0.96158
30	0.96535	0.96736
25	0.97035	0.97239
20	0.97605	0.97723
15	0.9815	0.98213
10	0.9866	0.98737
5	0.99335	0.99327
0	0.99835	1.00000

* Chaussier's alcohol had the specific gravity of 0.798; and Gilpin's that of 0.825. The tables of Gilpin are to be found in the Philosophical Transactions for 1794.

XVIII.—*Table, showing the Quantity of real Acid in Sulphuric Acid of different Densities.**

Real Acid per cent. by Weight.	Specific Gravities.	Real Acid per cent. by Weight.	Specific Gravities.
100	unknown	68	1.780
81	1.850	67	1.769
80	1.849	66	1.757
79	1.848	65	1.744
78	1.847	64	1.730
77	1.845	63	1.715
76	1.842	62	1.699
75	1.838	61	1.684
74	1.833	60	1.670
73	1.827	50	1.520
72	1.819	40	1.408
71	1.810	30	1.300
70	1.801	20	1.200
69	1.791	10	1.100

XIX.—*Table, showing the Quantity of pure Ammonia condensed in Solutions of different Specific Gravities.*

Specific Gravity (Water 1000.)	Grains of Ammonia in 100 Grs. of Solution.	Volume of Gas condensed.
850	35.3	494
860	32.6	456
870	29.9	419
880	27.3	382
890	24 7	346
900	22.2	311
910	19.8	277
920	17.4	244
930	15.1	211
940	12.8	180
950	10.5	147
960	8.3	116
970	6.2	87
980	4.1	57
990	2.	28

* For this and the nineteenth table, I am indebted to the obliging communication of Mr. Dalton. The table of the quantity of real acid in sulphuric acid of different densities, which has been copied from Mr. Kirwan into almost every elementary book, he finds to be deficient in accuracy. Even Mr. Davy's table of the quantity of ammonia in various solutions of that alkali, Mr. Dalton has found not to correspond exactly with his own experiments, the results of which are expressed in table XIX.

No. II.

ADMEASUREMENT AND EFFECTS OF HEAT.

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I.—*Correspondence between different Thermometers.*

FAHRENHEIT's thermometer is universally used in this kingdom. In this instrument the range between the freezing and boiling points of water is divided into 180°; and as the greatest possible degree of cold was supposed to be that produced by mixing snow and muriate of soda, it was made the zero. Hence the freezing point became 32°, and the boiling point 212°.

The Centigrade thermometer places the zero at the freezing point, and divides the range between it and the boiling point into 100°. This has long been used in Sweden under the title of Celsius's thermometer.

Reaumur's thermometer, which was formerly used in France, divides the space between the freezing and boiling of water into 80°, and places the zero at the freezing point.

Wedgwood's pyrometer is only intended to measure very high temperatures. Its zero corresponds with 1077° of Fahrenheit's, and each degree of Wedgwood is equal to 130° of Fahrenheit.

De Lisle's thermometer is used in Russia. The graduation begins at the boiling point, and increases towards the freezing point. The boiling point is marked 0, and the freezing point 150.

Therefore $180°$ F. $= 100°$ C. $= 80°$ R. $= 150°$ D. $= \dfrac{18}{13}$ W.

1. To reduce centigrade degrees to those of Fahrenheit, multiply by 9 and divide by 5, and to the quotient add 32, that is, $\dfrac{C. \times 9}{5} + 32 = F.$

2. To reduce Fahrenheit's degrees to centigrade, $\dfrac{F. - 32 \times 5}{9} = C.$

3. To reduce Reaumur's to Fahrenheit's we have the following formula, $\dfrac{R. \times 9}{4} + 32 = F.$

4. To convert Fahrenheit to Reaumur, $\dfrac{F. - 32 \times 4}{9} = R.$

5. To reduce De Lisle's degrees under the boiling point, we

have F. $= 212 - \dfrac{D. \times 6}{5}$. To reduce those above the boiling

point, F. $= 312 \times \dfrac{D. \times 6}{5}$.

6. And, inversely, to reduce Fahrenheit's degrees to De Lisle's, under the boiling point $\dfrac{1060 - 5\,F.}{6} = D.$; above the boiling point

$\dfrac{F. \times 5 - 1060}{6} = D.$

7. To reduce Wedgwood's degrees to those of Fahrenheit, we have $W \times 130 + 1077 = F.$

8. Inversely, to reduce Fahrenheit to Wedgwood, $\dfrac{F. - 1077}{130} = W.$

Table, showing the Correspondence between the Degrees of Fahrenheit's Thermometer and the new Scale of Mr. Dalton (see vol. i. page 89.)

Fahrenheit's Scale.	Fahrenheit's Scale, corrected for the Expansion of Glass.	True equal Intervals of Temperature.
— 40.		— 175
— 21.12		— 68
— 17.06		— 58
— 12.96		— 48
— 8.52		— 38
— 3.76		— 28
+ 1.34		— 18
6.78		— 8
12.63		+ 2
18.74		12
25.21		22
32.	32.	32
39.1	39.3	42
46.6	47.	52
54.44	55.	62
62.55	63.3	72
71.04	72.	82
79.84	81.	92
89.02	90.4	102
98.49	101.1	112
108.3	110.	122
118.5	120.1	132
129.	130.4	142
139.9	141.1	152
151.	152.	162
162.4	163.3	172
177.4	175.	182
186.5	186.9	192
199.	199.2	202
212.	212.	212
359.1		312
539.8		412
754.7		512
1000.		612
1285.		712

II.—*Table of the Effects of Heat.*

1.—*Freezing Points of Liquids.*

Fahrenheit.	
—55	Strongest nitric acid freezes (Cavendish)
46	Ether and liquid ammonia
39	Mercury
36	Sulphuric acid (Thomson)
22	Acetous acid
11	2 Alcohol, 1 water
7	Brandy
+ 1	Strongest sulphuric acid (Cavendish)
16	Oil of turpentine (Macquer)
20	Strong wines
23	Fluoric acid
	Oils bergamot and cinnamon
25	Human blood
28	Vinegar
30	Milk
32	Oxymuriatic acid
	Water
36	Olive oil
46	Sulphuric acid, specific gravity 1.78 (Keir)
64	Oil of anniseeds, 50 (Thomson)

2.—*Melting Points of Solids.*

40	Equal parts sulphur and phosphorus
82	Adipocire of muscle
97	Lard (Nicholson)
99	Phosphorus (Pelletier)
104	Resin of bile
109	Myrtle wax (Cadet)
112	Spermaceti (Bostock)
127	Tallow (Nicholson) 92 (Thomson)
149	Bees' wax
145	Ambergris (La Grange)
155	Bleached wax (Nicholson)
212	Bismuth 5 parts, tin 3, lead 2
234	Sulphur (Hope) 212 (Fourc.) 185 (Kirw.)
235	Adipocire of biliary calculi (Fourcroy)
283	Tin and bismuth, equal parts
303	Camphor
334	Tin 3, lead 2, or tin 2, bismuth 1
442	Tin (Chrichton) 413 (Irvine)
460	Tin 1, lead 4
476	Bismuth (Irvine)
612	Lead (Chrichton) 594 (Irv.) 540 (Newton)
700	Zinc
809	Antimony

Fahren.	Wedg.	
3809	21	Brass
4587	27	Copper
4717	28	Silver
5237	32	Gold
17977	130	Cobalt
20577	150	Nickel
21097	154	Soft nails
21637	158	Iron
21877	160	Manganese
23177	+170	Platina, tungsten, molybdena, uranium, titanium, &c.

3. Solids and Liquids Volatilized.

98	Ether boils
140	Liquid ammonia boils
145	Camphor sublimes (Venturi)
170	Sulphur evaporates (Kirwan)
176	Alcohol boils, 174 (Black)
212	Water and essential oils boil
219	Phosphorus distils (Pelletier)
230	Muriate of lime boils (Dalton)
242	Nitrous acid boils
248	Nitric acid boils
283	White arsenic sublimes
540	Metallic arsenic sublimes
554	Phosphorus boils
560	Oil of turpentine boils, about 212° (Dal.)
570	Sulphur boils
590	Sulphuric acid boils (Dalton) 546 (Black)
600	Linseed oil boils, sulphur sublimes (Davy)
660	Mercury boils (Dalton) 644 (Secondat) 600 (Black) 672 (Irvine)

4. Miscellaneous Effects of Heat.

—90	Greatest cold produced by Mr. Walker
50	Natural cold observed at Hudson's Bay
33	Observed on the surface of the snow at Glasgow, 1780
14	At Glasgow, 1780
0	Equal parts, snow and salt
+43	Phosphorus burns slowly
59	Vinous fermentation begins
66	to 135, Animal putrefaction
75	to 80, Summer heat in this Climate
77	Vinous fermentation rapid, acetous begins
80	Phosphorus burns in oxygen, 104 (Gottling)
88	Acetification ceases
96	to 100, Animal temperature

Fähren.	Wedg.	
107		Feverish heat
122		Phosphorus burns vividly (Fourcroy) 148 (Thomson)
165		Albumen coagulates, 156 (Black)
303		Sulphur burns slowly
635		Lowest heat of ignition of iron in the dark
800		Hydrogen burns, 1000 (Thomson)
802		Charcoal burns (Thomson)
1050		Iron red in twilight
1207	1	Iron red in daylight
1337	+2	Azotic gas burns
1857	6	Enamel colours burned
2897	14	Diamond burns (M'Kenzie) 30 W = 5000 F. (Morveau)
6277	40	Delft ware fired
8487	57	Working heat of plate glass
10177	70	Flint glass furnace
12257	86	Cream-coloured ware fired
13297	94	Worcester china vitrified
14337	102	Stone ware fired
14727	105	Chelsea china fired
15637	112	Derby china fired
15897	114	Flint glass furnace greatest heat
16007	121	Bow china vitrified
16807	124	Plate glass greatest heat
17327	125	Smith's forge
20577	150	Hessian crucible fused
25127	185	Greatest heat observed

III.—*Table of the Force of Steam at different Temperatures of Fahrenheit's Scale from actual Experiment.*

(Betancourt in Prony's Architecture Hydraulique.)

Temperature.	Force in English Inches of Mercury.	Temperature.	Force in English Inches of Mercury.
32	0	162	9.07
42	.08	172	11.0
52	.21	182	14.9
62	.38	192	18.7
72	.58	202	23.7
82	.87	212	29.8
92	1.26	222	37.4
102	1.74	232	46.5
112	2.37	242	57.3
122	3.16	252	69.7
132	4.16	262	83.6
142	5.43	272	97.1
152	7.00	282	108.

In the 5th volume of " Memoirs of the Manchester Society," the following valuable table of the force of vapour, for each degree of Fahrenheit, is given by Mr. Dalton; the numbers below 212° from experiment, and the higher numbers from calculation. Mr. Betancourt, however, professes to have obtained all the above results from actual experiment.

Table of the Force of Vapour from Water in every Temperature from that of the Congelation of Mercury, or 40° below zero of Fahrenheit, to 325°.

Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.
— 40	.013	37	.237	80	1.00
— 30	.020	38	.245	81	1.04
— 20	.030	39	.254	82	1.07
— 10	.043	40	.263	83	1.10
		41	.273	84	1.14
0	.064	42	.283	85	1.17
1	.066	43	.294	86	1.21
2	.068	44	.305	87	1.24
3	.071	45	.316	88	1.28
4	.074	46	.328	89	1.32
5	.076	47	.339	90	1.36
6	.079	48	.351	91	1.40
7	.082	49	.363	92	1.44
8	.085	50	.375	93	1.48
9	.087	51	.388	94	1.53
10	.090	52	.401	95	1.58
11	.093	53	.415	96	1.63
12	.096	54	.429	97	1.68
13	.100	55	.443	98	1.74
14	.104	56	.458	99	1.80
15	.108	57	.474	100	1.86
16	.112	58	.490	101	1.92
17	.116	59	.507	102	1.98
18	.120	60	.524	103	2.04
19	.124	61	.542	104	2.11
20	.129	62	.560	105	2.18
21	.134	63	.578	106	2.25
22	.139	64	.597	107	2.32
23	.144	65	.616	108	2.39
24	.150	66	.635	109	2.46
25	.156	67	.655	110	2.53
26	.162	68	.676	111	2.60
27	.168	69	.698	112	2.68
28	.174	70	.721	113	2.76
29	.180	71	.745	114	2.84
30	.186	72	.770	115	2.92
31	.193	73	.796	116	3.00
		74	.823	117	3.08
32	.200	75	.851	118	3.16
33	.207	76	.880	119	3.25
34	.214	77	.910	120	3.33
35	.221	78	.940	121	3.42
36	.229	79	.971	122	3.50

Table of the Force of Vapour, &c.—continued.

Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.
123	3.59	168	11.54		
124	3.69	169	11.83	213	30.60
125	3.79	170	12.13	214	31.21
126	3.89	171	12.43	215	31.83
127	4.00	172	12.73	216	32.46
128	4.11	173	13.02	217	33.09
129	4.22	174	13.32	218	33.72
130	4.34	175	13.62	219	34.35
131	4.47	176	13.92	220	34.99
132	4.60	177	14.22	221	35.63
133	4.73	178	14.52	222	36.25
134	4.86	179	14.83	223	36.88
135	5.00	180	15.15	224	37.53
136	5.14	181	15.50	225	38.20
137	5.29	182	15.86	226	38.89
138	5.44	183	16.23	227	39.59
139	5.59	184	16.61	228	40.30
140	5.74	185	17.00	229	41.02
141	5.90	186	17.40	230	41.75
142	6.05	187	17.80	231	42.49
143	6.21	188	18.20	232	43.24
144	6.37	189	18.60	233	44.00
145	6.53	190	19.00	234	44.78
146	6.70	191	19.42	235	45.58
147	6.87	192	19.86	236	46.39
148	7.05	193	20.32	237	47.20
149	7.23	194	20.77	238	48.02
150	7.42	195	21.22	239	48.84
151	7.61	196	21.68	240	49.67
152	7.81	197	22.13	241	50.50
153	8.01	198	22.69	242	51.34
154	8.20	199	23.16	243	52.18
155	8.40	200	23.64	244	53.03
156	8.60	201	24.12	245	53.88
157	8.81	202	24.61	246	54.68
158	9.02	203	25.10	247	55.54
159	9.24	204	25.61	248	56.42
160	9.46	205	26.13	249	57.31
161	9.68	206	26.66	250	58.21
162	9.91	207	27.20	251	59.12
163	10.15	208	27.74	252	60.05
164	10.41	209	28.29	253	61.00
165	10.68	210	28.84	254	61.92
166	10.96	211	29.41	255	62.85
167	11.25	212	30.00	256	63.76

Table of the Force of Vapour, &c.—continued.

Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.	Temperature.	Force of Vapour in Inches of Mercury.
257	64.82	280	88.75	303	115.32
258	65.78	281	89.87	304	116.50
259	66.75	282	90.99	305	117.68
260	67.73	283	92.11	306	118.86
261	68.72	284	93.23	307	120.03
262	69.72	285	94.35	308	121.20
263	70.73	286	95.48	309	122.37
264	71.74	287	96.64	310	123.53
265	72.76	288	97.80	311	124.69
266	73.77	289	98.96	312	125.85
267	74.79	290	100.12	313	127.00
268	75.80	291	101.28	314	128.15
269	76.82	292	102.45	315	129.29
270	77.85	293	103.63	316	130.43
271	78.89	294	104.80	317	131.57
272	79.94	295	105.97	318	132.72
273	80.98	296	107.14	319	133.86
274	82.01	297	108.31	320	135.00
275	83.13	298	109.48	321	136.14
276	84.35	299	110.64	322	137.28
277	85.47	300	111.81	323	138.42
278	86.50	301	112.98	324	139.56
279	87.63	302	114.15	325	140.70

IV.—*Table of the Expansion of Air by Heat.*
(Communicated by Mr. Dalton.)

Fahren.		Fahren.		Fahren.		Fahren.	
32	1000	53	1050	74	1097	95	1142
33	1002	54	1052	75	1099	96	1144
34	1004	55	1055	76	1101	97	1146
35	1007	56	1057	77	1104	98	1148
36	1009	57	1059	78	1106	99	1150
37	1012	58	1062	79	1108	100	1152
38	1015	59	1064	80	1110	110	1173
39	1018	60	1066	81	1112	120	1194
40	1021	61	1069	82	1114	130	1215
41	1023	62	1071	83	1116	140	1235
42	1025	63	1073	84	1118	150	1255
43	1027	64	1075	85	1121	160	1275
44	1030	65	1077	86	1123	170	1295
45	1032	66	1080	87	1125	180	1315
46	1034	67	1082	88	1128	190	1334
47	1036	68	1084	89	1130	200	1354
48	1038	69	1087	90	1132	210	1372
49	1040	70	1089	91	1134	212	1376
50	1043	71	1091	92	1136		
51	1045	72	1093	93	1138		
52	1047	73	1095	94	1140		

V.—*Table of the Expansion of Liquids by Heat.*

Temp.	Mercury.	Linseed Oil.	Sulphuric Acid.	Nitric Acid.	Water.	Oil of Turpentine.	Alcohol.
32°	100000	100000					100000
40	100081		99752	99514			100539
50	100183		100000	100000	100023	100000	101105
60	100304		100279	100486	100091	100460	101688
70	100406		100558	100990	100197	100993	102281
80	100508		100806	101530	100332	101471	102890
90	100610		101054	102088	100694	101931	103517
100	100712	102760	101317	102620	100908	102446	104162
110	100813		101540	103196		102943	
120	100915		101834	103776	101404	103421	
130	101017		102097	104352		103954	
140	101119		102320	105132		104573	
150	101220		102614		102017		
160	101322		102893				
170	101424		103116				
180	101526		103339				
190	101628		103587		103617		
200	101730		103911				
212	101835	107250			104577		

VI.—*Table of the Expansion of Water by Heat.*

(From Mr. Dalton's New System of Chemical Philosophy.)

Temperature.	Expansion.	Temperature.	Expansion.
12° Fahren.	100236	122° Fahren.	101116
22	100090	132	101367
32	100022	142	101638
42	100000	152	101934
52	100021	162	102245
62	100083	172	102575
72	100180	182	102916
82	100312	192	103265
92	100477	202	103634
102	100672	212	104012
112	100880		

VII.—*Table of the Expansion of Solids by Heat.*

Temp.	Platina.†	Antimon.	Steel.	Iron.	Cast Iron.	Bismuth.
32°	120000	120000	120000	120000	120000	120000
212	120104	120130	120147	120151		120167
White ⎬ heat* ⎭			123428	121500	122571	

Temp.	Copper.	Cast Brass.	Brass Wire.	Tin.	Lead.	Zinc.
32°	120000	120000	120000	120000	120000	120000
212	120204	120225	120232	120298	120344	120355

Temp.	Hamm'd Zinc.	Zinc 8 Tin 1	Lead 2 Tin 1	Brass 2 Zinc 1	Pewter.	Copper 3 Tin‡ 1
32°	120000	120000	120000	120000	120000	120000
212	120373	120323	120301	120247	120274	120218

Expansion of Glass.

Temp.	Bulk.	Temp.	Bulk.	Temp.	Bulk.
32°	100000	100°	100023	167°	100056
50	100006	120	100033	190	100069
70	100014	150	100044	212	100083

* Rinman.

† Borda.

‡ The metal, whose expansion is here given, was an alloy composed of three parts of copper, and one of tin. The figures in some of the preceding columns are to be understood in the same manner. Thus, in the last column but two, the metal consisted of two parts of brass, alloyed with one of zinc.

VIII.—*Tables, exhibiting a collective View of all the Frigorific Mixtures, contained in Mr. Walker's Publication, 1808.*
(Communicated by Mr. Walker.)

1.—*Table, consisting of Frigorific Mixtures, having the Power of generating or creating Cold, without the Aid of Ice, sufficient for all useful and philosophical Purposes, in any Part of the World, at any Season.*

Frigorific Mixtures, without Ice.

MIXTURES.		Thermometer sinks.	Deg. of cold produced.
Muriate of ammonia Nitrate of potash Water	5 parts 5 16	From + 50° to + 10°	40
Muriate of ammonia Nitrate of potash Sulphate of soda Water	5 parts 5 8 16	From + 50° to + 4°	46
Nitrate of ammonia Water	1 part 1	From + 50° to + 4°	46
Nitrate of ammonia Carbonate of soda Water	1 part 1 1	From + 50° to — 7°	57
Sulphate of soda Diluted nitric acid	3 parts 2	From + 50° to — 3°	53
Sulphate of soda Muriate of ammonia Nitrate of potash Diluted nitric acid	6 parts 4 2 4	From + 50° to — 10°	60
Sulphate of soda Nitrate of ammonia Diluted nitric acid	6 parts 5 4	From + 50° to — 14°	64
Phosphate of soda Diluted nitric acid	9 parts 4	From + 50° to —12°	62
Phosphate of soda Nitrate of ammonia Diluted nitric acid	9 parts 6 4	From + 50° to — 21°	71
Sulphate of soda Muriatic acid	8 parts 5	From + 50° to 0°	50
Sulphate of soda Diluted sulphuric acid	5 parts 4	From + 50° to + 3°	47

N. B.—If the materials are mixed at a warmer temperature than that expressed in the table, the effect will be proportionably greater; thus, if the most powerful of these mixtures be made, when the air is + 85°, it will sink the thermometer to + 2°.

2.—*Table, consisting of Frigorific Mixtures, composed of Ice,
with chemical Salts and Acids.*

Frigorific mixtures with Ice.

MIXTURES.		Thermometer sinks.	Deg. of cold produced.
Snow, or pounded ice	2 parts	to — 5°	•
Muriate of soda	1		
Snow, or pounded ice	5 parts	to — 12°	•
Muriate of soda	2		
Muriate of ammonia	1		
Snow, or pounded ice	24 parts	to — 18°	•
Muriate of soda	10		
Muriate of ammonia	5		
Nitrate of potash	5		
Snow, or pounded ice	12 parts	to — 25°	•
Muriate of soda	5		
Nitrate of ammonia	5		
Snow	3 parts	From + 32° to — 23°	55
Diluted sulphuric acid	2		
Snow	8 parts	From + 32° to — 27°	59
Muriatic acid	5		
Snow	7 parts	From + 32° to — 30°	62
Diluted nitric acid	4		
Snow	4 parts	From + 32° to — 40°	72
Muriate of lime	5		
Snow	2 parts	From + 32° to — 50°	82
Chryst. muriate of lime	3		
Snow	3 parts	From + 32° to — 51°	83
Potash	4		

(Note: The "Thermometer sinks" column for the first four mixtures is bracketed together and labelled vertically "From any temperature.")

N. B.—The reason for the omissions in the last column of this table is, the thermometer sinking in these mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing.

3.—*Table, consisting of Frigorific Mixtures selected from the foregoing Tables, and combined so as to increase or extend Cold to the extremest Degrees.*

Combinations of Frigorific Mixtures.

MIXTURES.		Thermometer sinks.	Deg. of cold produced.
Phosphate of soda	5 parts		
Nitrate of ammonia	3	From 0° to — 34°	34
Diluted nitric acid	4		
Phosphate of soda	3 parts		
Nitrate of ammonia	2	From — 34° to — 50°	16
Diluted mixed acids	4		
Snow	3 parts	From 0° to — 46°	46
Diluted nitric acid	2		
Snow	8 parts		
Diluted sulphuric acid	3 ⎱	From — 10° to — 56°	46
Diluted nitric acid	3 ⎰		
Snow	1 part	From — 20° to — 60°	40
Diluted sulphuric acid	1		
Snow	3 parts	From + 20° to — 48°	68
Muriate of lime	4		
Snow	3 parts	From + 10° to — 54°	64
Muriate of lime	4		
Snow	2 parts	From — 15° to — 68°	53
Muriate of lime	3		
Snow	1 part	From 0° to — 66°	66
Chryst. muriate of lime	2		
Snow	1 part	From — 40° to — 73°	33
Chryst. muriate of lime	3		
Snow	8 parts	From — 68° to — 91°	23
Diluted sulphuric acid	10		

N. B.—The materials in the first column are to be cooled, previously to mixing, to the temperature required, by mixtures taken from either of the preceding tables.

IX.—*Table of the Specific Heats or Capacities of Bodies, altered from Dr. Thomson's System of Chemistry, 3d Edition.*

N. B.—The bodies compared are taken in equal weights, and the specific heat of water is assumed to be 1.

1.—GASES.

Hydrogen	21.4000 (c.)
Oxygen	4.7490 (c.)
Common air	1.7900 (c.)
Carbonic acid	1.0459 (c.)
Azote	0.7036 (c.)

2.—WATER.

Ice	0.9000 (K.)
Water	1.0000
Steam	1.5500 (c.)

3.—SALINE SOLUTIONS.

Carbonate of ammonia	1.851 (c.)
Sulphuret of do. (0.818)	0.994 (c.)
Sulphate of magnesia 1 / Water 2	0.844 (c.)
Muriate of soda 1 / Water 8	0.832 (c.)
Nitrate of potash 1 / Water 8	0.8167 (L.)
Ditto	0.914 (I.)
Nitrate of potash 1 / Water 3	0.646 (K.)
Muriate of ammonia 1 / Water 1.5	0.798 (K.)
Super-tartrate of potash 1 / Water 273.3	0.765 (K.)
Sulphate of iron 1 / Water 2.5	0.734 (K.)
Sulphate of soda 1 / Water 2.9	0.728 (K)
Alum 1 / Water 2.9	0.649 (K.)
Nitric acid $9\frac{1}{3}$ / Lime 1	0.6189 (L.)
Solution of brown sugar	1.086 (K)

4.—ACIDS AND ALKALIS.

Nitric acid (1.2989)	pale	0.844 (K.)
		0.6613 (L.)
		0.62 (LE.)
	(1.355)	0.570 (K.)
Muriatic acid	(1.122)	0.680 (K.)
Sulphuric acid	(1.885)	0.758 (K.)
	(1.872)	0.429 (K.)
	do.	0.34 (LE.)
	(1.87)	0.3345 (L.)
Do. 4, Water 5		0.6631 (L.)
Do. 4, do. 3		0.6031 (L.)
Potash	(1.346)	0.759 (K.)
Ammonia	(0.997)	0.708 (K.)

5.—INFLAMMABLE LIQUIDS.

Alcohol	0.6666 (c.)
	0.64 (LE.)
	0.6024 (c.)
	1.086 (K.)
Oil of olives	0.716 (K.)
	0.500 (LE.)
Linseed oil	0.528 (K.)
Spermaceti	0.5000 (c.)
Oil of turpentine	0.472 (K.)
Spermaceti	0.399 (K.)

6.—ANIMAL FLUIDS.

Arterial blood	1.0300 (c.)
Venous blood	0.8928 (c.)
Cow's milk	0.9999 (c.)

7.—ANIMAL SOLIDS.

Ox-hide, with hair	0.7870 (c.)
Lungs of a sheep	0.7690 (c.)
Lean of ox-beef	0.7400 (c.)

8.—VEGETABLE SOLIDS.

Pinus sylvestris	0.65 (M.)
Pinus abies	0.60 (M.)
Tilea Europæa	0.62 (M.)
Pinus picea	0.58 (M.)
Pyrus malus	0.57 (M.)
Betula alnus	0.53 (M.)

(C.) Crawford; (I.) Irvine, jun.; (K.) Kirwan; (L.) Lavoisier and La Place; (LE.) Leslie; (M.) Meyer; (R.) Rumford; (W.) Wilcke.

Quercus robur ses-silis	0.51	(M.)
Fraxinus excelsior	0.51	(M.)
Pyrus communis	0.50	(M.)
Rice	0.5050	(c.)
Horse beans	0.5020	(c.)
Dust of the pine tree	0.5000	(c.)
Peas	0.4920	(c.)
Fagus sylvatica	0.49	(M.)
Carpinus betulus	0.48	(M.)
Betula alba	0.48	(M.)
Wheat	0.4770	(M.)
Elm	0.47	(M.)
Quercus robur pe-dunculata	0.45	(M.)
Prunus domestica	0.44	(M.)
Diaspyrus ebenum	0.43	(M)
Barley	0.4210	(c.)
Pit coal	0.2777	(c.)
Charcoal	0.2631	(c.)
Oats	0 4160	(c.)
Cinders	0.1923	(c.)

9.—EARTHY BODIES, STONE WARE, AND GLASS.

Chalk	0.2564	(c.)
Quicklime	0.2229	(c.)
	0.2168	(L.)
Ashes of pit coal	0.1855	(c.)
———— elm	0.1402	(c.)
Agate	0.195	(w.)
Stone ware	0.195	(K.)
Crystal	0.1929	(L.)
Swedish glass	0.187	(w.)
Flint glass	0.174	(K.)

10.—SULPHUR 0.183

11.—METALS.

Iron	0.125	(K.)
	0.1269	(c.)
	0.126	(w.)
Brass	0.1123	(c.)
	0.116	(w.)

Copper	0.1111	(c.)
	0.114	(w.)
Sheet iron	0.1099	(L.)
Gun metal	0.1100	(R.)
Zinc	0.0943	(c.)
	0.102	(w.)
Silver	0.082	(w.)
Tin	0.068	(K.)
	0.0704	(L.)
	0.060	(w.)
Antimony	0.086	(K.)
	0.0645	(c.)
	0.063	(w.)
Gold	0.050	(w.)
Lead	0.050	(K.)
	0.0352	(c.)
	0.042	(w.)
Bismuth	0.043	(w.)
Mercury	0.053	(K.)
	0.0357	(c.)
	0.0290	(L.)

12.—METALLIC OXIDES.

Oxide of iron	0.320	(K.)
Rust of iron	0.2500	(c.)
Do. nearly freed from air	0.1666	(c.)
White oxide of antimony washed	0.220	(K.)
	0.2272	(c.)
Do nearly freed from air	0.1666	
Oxide of copper do.	0.2272	(c.)
Oxide of lead and tin	0.102	(K.)
Oxide of zinc	0.1369	(c.)
Oxide of tin, near-ly freed from air	0.0990	(c.)
	0.096	(K.)
Yellow oxide of lead	0.0680	(c.)
	0.068	(K.)

X.—*Table of Specific Heats, from Mr. Dalton's New System of Chemical Philosophy*, Part 1.*

GASES.	Equal Weights.	Equal Bulks.	SOLIDS.	Eq. Wts.	Eq. Blks.
Hydrogen	21.40	.002	Ice	.90 ?	.83
Oxygen	4.75	.006	Dried woods, and		
Common air	1.79	.002	other vegetable		
Carbonic acid	1.05	.002	substances, from		
Azotic	.79	.001	.45 to	.65	
Aqueous vapour	1.55	.001	Quicklime	.30	
			Pit-coal (1.27)	.28	.36
			Charcoal	.26	
LIQUIDS.			Chalk	.27	.67
			Hydrat. lime	.25	
Water	1.00	1.00	Flint glass (2.87)	.19	.55
Arterial blood	1.03		Muriate of soda	.23	
Milk (1.026)	.98	1.00	Sulphur	.19	
Carbonate of ammon. (1.035)	.95	.98	Iron	.13	1.00
Carbonate of potash (1.30)	.75	.98	Brass	.11	.97
Solution of ammonia (.948)	1.03	.98	Copper	.11	.98
Common vinegar (1.02)	.92	.94	Nickel	.10	.78
Venous blood	.89		Zinc	.10	.69
Solut. of common salt (1.197)	.78	.93	Silver	.08	.84
Solut. of sugar (1.17)	.77	.90	Tin	.07	.51
Nitric acid (1.20)	.76	.96	Antimony	.06	.40
Nitric acid (1.30)	.68	.88	Gold	.05	.97
Nitric acid (1.36)	.63	.85	Lead	.04	.45
Nitrate of lime (1.40)	.62	.87	Bismuth	.04	.40
Sulph. acid and water, equal b	.52	.80			
Muriatic acid (1.153)	.60	.70	Oxides of the		
Acetic acid (1.036)	.66	.70	metals surpass the		
Sulphuric acid (1.844)	.35	.65	metals themselves,		
Alcohol (.85)	.76	.65	according to Craw-		
Alcohol (.817)	.70	.57	ford.		
Sulphuric ether (.76)	.66	.50			
Spermaceti oil (.87)	.52	.45			
Mercury	.04	.55			

* I have added this table, though in some degree a repetition of the preceding one; because the bodies compared are taken in equal bulks, as well as in equal weights.

No. III.

I.—*Table of the Solubility of Salts in Water.*

NAMES OF SALTS.	Solubility in 100 Parts Water.	
	At 60°	At 212°
ACIDS.		
Arsenic - - - -	150.	
Benzoic - - - -	0.208	4.17
Boracic - - - -		2.
Camphoric - - - -	1.04	8.3
Citric - - - -	133.	200.
Gallic - - - -	8.3	66.
Mucic - - - -	0.84	1.25
Molybdenic - - - -		0.1
Oxalic - - - -	50.	100.
Suberic - - - -	0.69	50.
Succinic - - - -	4.	50.
Tartaric - - - -	Very soluble	
SALIFIABLE BASES.		
Barytes - - - -	5.	50.
crystallized - -	57.	Unlimited
Lime - - - -	0.2	
Potash - - - -	Very soluble	
Soda - - - -	do.	
Strontites - - - -	0.6	
crystallized - -	1.9	50.
SALTS.		
Acetate of ammonia - -	Very soluble	
barytes - -	do.	
lime - - -	do.	
magnesia - -	do.	
Acetate of potash - -	100.	
soda - -	Very soluble	
strontites -		40.
Carbonate of ammonia -	+ 30.	100.
barytes - -	Insoluble	
lime - -	do.	
magnesia - -	2.	
potash - -	25.	83.
soda - -	50.	+ 100.
strontites - -	Insoluble	

Table of the Solubility of Salts in Water—Continued.

NAMES OF SALTS.	Solubility in 100 Parts Water.	
	At 60°	At 212°
SALTS.		
Camphorate of ammonia -	1.	33.
barytes - -	0.16	
lime - -	0.5	
potash - -	33.	+ 33.
Citrate of soda - - -	60.	
lime - -	Insoluble	
Hyper-oxymuriate of barytes -	25.	+ 25.
mercury -	25.	
potash -	6.	40.
soda -	35.	+ 35.
Muriate of ammonia - -	33.	100.
barytes - -	20.	+ 20.
lead - - -	4.5	
lime - - -	200.	
magnesia - -	100.	
mercury - -	5.	50.
potash - -	33.	
silver - -	$0.\frac{1}{30}$	
soda - - -	35.42	36.16
strontites - -	150.	Unlimited
Nitrate of ammonia - -	50.	200.
barytes - -	8.	25.
lime - - -	400.	
magnesia - -	100.	+ 100.
potash - -	14.25	100.
soda - - -	33.	+ 100.
strontites - -	100.	200.
Oxalate of strontites -, -	$0.\frac{1}{19}$	
Phosphate of ammonia - -	25.	+ 25.
barytes - -	0.	0.
lime - -	0.	0.
magnesia - -	6.6	
potash - -	Very soluble	
soda - -	25.	50.
strontites - -	0.	0.
Phosphate of ammonia - -	50.	+ 50.
barytes - -	$0.\frac{1}{4}$	
potash - -	33.	+ 33.
Sulphate of ammonia - -	50.	100.
barytes - -	0.002	
copper - -	25.	50.
iron - -	50.	+ 100.
lead - -	$0.\frac{1}{12}$	
lime - -	0.2	0.22
magnesia - -	100.	133.

Table of the Solubility of Salts in Water—Continued.

NAMES OF SALTS.	Solubility in 100 Parts Water,	
	At 60°	At 212°
SALTS.		
Sulphate of potash - -	6.25	20.
soda - -	37.	125.
strontites - -	0.	0.02
Sulphite of ammonia - -	100.	
lime - -	0.125	
magnesia - -	5.	
potash - -	100.	
soda - -	25.	100.
Saccholactate of potash - -		12.
soda - -		20.
Sub-borate of soda (borax) -	8.4	16.8
Super-sulphate of alumine and		
potash (alum) - -	5.	133.
potash -	50.	+ 100.
Super-oxalate of potash -		10.
tartrate of potash -	$1.\frac{2}{3}$	$3.\frac{1}{3}$
Tartrate of potash - -	25.	
and soda -	20.	
antimony and potash	6.6	33.

II.—*Table of Substances soluble in Alcohol.*

NAMES OF SUBSTANCES.	Tempera-ture.	100 Parts Alco-hol dissolve
Acetate of copper - -	176°	7.5
soda - - -	176°	46.
Arsenate of potash - -	do.	3.75
soda - - -	do.	1.7
Boracic acid - - -	do.	20.
Camphor - - - -	do.	75.
Muriate of ammonia - -	do.	7.
alumine - -	$54\frac{1}{2}°$	100.
copper - -	176°	100.
iron - - -	176°	100.
lime - - -	do.	100.
magnesia - -	do.	547.
mercury - -		88.3
zinc - - -	$54\frac{1}{2}°$	100.
Nitrate of ammonia - -	176°	89.2
alumine - -	$54\frac{1}{2}°$	100.
cobalt - - -	$54\frac{1}{2}°$	100.
lime - - -		125.
potash - -	176°	2.9
silver - - -	do.	41.7
Succinic acid - - -	do.	74.
Sugar, refined - - -	do.	$24\frac{1}{2}$.
Super-oxalate of potash - -		S.
Tartrate of potash - -		0.04

OTHER SUBSTANCES SOLUBLE IN ALCOHOL.—All the acids, except the sulphuric, nitric, and oxymuriatic, which decompose it, and the phosphoric and metallic acids.—Potash, soda, and ammonia, very soluble. Soaps; extract; tan; volatile oils; adipocire; resins; urea.

SUBSTANCES INSOLUBLE, OR VERY SPARINGLY SOLUBLE, IN ALCOHOL.—Earths; phosphoric and metallic acids; almost all sulphates and carbonates; the nitrates of lead and mercury; the muriates of lead, silver, and soda (the last, *per* Chenevix, sparingly soluble;) the sub-borate of soda; the tartrate of soda and potash, and super-tartrate of potash; fixed oils; wax; starch; gum; caoutchouc; woody fibre; gelatine; albumen, and gluten.

III.—Kirwan's Table, showing the Composition of Salts.

COMPONENT PARTS.

SALTS.	BASIS.	ACID.	WATER.	STATE.
Carbonate of potash	41.	43.	16.	Crystallized.
Pearlash	60.	30.	6.	Dry.
Carbonate of soda	21.58	14.42	64.	Fully crystallized.
ditto	59.86	40.05		Desiccated.
barytes	78.	22.		Natural or ignited.
strontian	69.5	30.		Natural or ignited.
lime	55.	45.		Natural if pure, or artificial ignited.
magnesia	25.	50.	25.	Crystallized.
common ditto	45.	34.	21.	Dried at 80°.
Sulphate of potash	54.	45.2		Dry.
soda	18.48	23.52	58.	Fully crystallized.
ditto	44.	56.		Desiccated at 700°.
ammonia	14.24	54.66	31.1	Natural and pure, artificial ignited.
barytes	66.66	33.33		Natural and pure, artificial ignited.
strontian	58.	42.		Dried at 66°.
lime	32	46.	22.	Dried at 170°.
ditto	35.23	50.39	14.38	Ignited.
ditto	38.81	55.84	5.35	Incandescent.
ditto	41.	59.		Fully crystallized.
magnesia	17.	29.35	53.65	Desiccated.
ditto	36.68	63.32		Crystallized,
Alum	12. ignited	17.66	51. of crystals +19.24 in the earth.	Desiccated at 700°.
Ditto	63.75	36.25		

Table, showing the Composition of Salts,—Continued.

COMPONENT PARTS.

SALTS.	BASIS.	ACID.	WATER.	STATE.
Nitrate of potash	51.8	44.	4.2 of Composition	Dried at 70°.
soda	40.58	53.21	6.21 of Composition	Dried at 400°.
ditto	42.34	57.55		Ignited.
ammonia	23.	57.	20.	Crystallized.
barytes	57.	32.	11.	Crystallized.
strontian	36.21	31.07	32.72	Well dried, that is, in air.
lime	32.	57.44	10.56	Crystallized.
magnesia	22.	46.	22.	Dried at 80°.
Muriate of potash	64.	36.		Dried at 80°.
soda	53.	47. aqueous, 38.88 real		Crystallized.
ammonia	25.	42.75	32.25	Sublimed.
ditto	64.	20.	16.	Crystallized.
barytes	76.2	23.8		Desiccated.
ditto	40.	18.	42.	Crystallized.
strontian	69.	31.		Desiccated.
lime	50.	42.	8.	Red hot.
magnesia	31.07	34.59	34.34	Sensibly dry.

IV.—*Table of Incompatible Salts.**

SALTS.	INCOMPATIBLE WITH
1. Fixed alkaline sulphates	Nitrates of lime and magnesia, Muriates of lime and magnesia.
2. Sulphate of lime	Alkalis, Carbonate of magnesia, Muriate of barytes.
3. Alum	Alkalis, Muriate of barytes, Nitrate, muriate, carbonate of lime, Carbonate of magnesia.
4. Sulphate of magnesia	Alkalis, Muriate of barytes, Nitrate and muriate of lime.
5. Sulphate of iron	Alkalis, Muriate of barytes, Earthy carbonates.
6. Muriate of barytes	Sulphates, Alkaline carbonates, Earthy carbonates.
7. Muriate of lime	Sulphates, except of lime, Alkaline carbonates, Carbonate of magnesia.
8. Muriate of magnesia	Alkaline carbonates, Alkaline sulphates.
9. Nitrate of lime	Alkaline carbonates, Carbonates of magnesia and alumine, Sulphates, except of lime.

V.—*Quantity of Real Acid taken up by mere Alkalis and Earths (Kirwan.)*

100 Parts.	Sulphuric.	Nitric.	Muriatic.	Carbonic acid.
Potash	82.48	84.96	56.3	105, almost
Soda	127.68	135.71	73.41	66.8
Ammonia	383.8	247.82	171.	Variable
Baryt.	50.	56.	31.8	282.
Strontia	72.41	85.56	46.	43.2
Lime	143.	179.5	84.488	81.81
Magnesia	172.64	210.	111.35	200. Fourcroy
Alumine	150.9			335, nearly, Bergman

VI.—*Quantity of Alkalis and Earths taken up by 100 Parts of real Sulphuric, Nitric, Muriatic, and Carbonic Acids, Saturated (Kirwan.)*

100 Parts.	Potash.	Soda.	Ammonia.	Baryt.	Strontia.	Lime.	Mag.
Sulphuric	121.48	78.32	26.05	200.	138.	70.	57.92
Nitrous	117.7	73.3	40.35	178.12	116.86	55.7	47.64
Muriatic	177.6	136.2	58.48	314.46*	216.21	118.3	898.
Carbonic	95.1	149.6		354.5	231. +	122.	50.

* That is, salts which cannot exist together in solution, without mutual decomposition.

VII.—*Table, by Richter, of the Quantity of each Base required for the Saturation of the different Acids.*

(From Berthollet's *Statique Chimique*, 1re *Partie*, p. 136.

The experiments, from which the following table was deduced, we are assured by Berthollet, were the principal occupation of Richter from the year 1791 to 1800; and, from the attention with which they were performed, appear to be deserving of considerable confidence. An example will best explain the method of using the table. Take the article *potash* in the first column, opposite to which is placed the number 1605. The numbers in the other column show how much of each acid is required to saturate 1605 parts of potash, *viz.* 427 parts of fluoric acid, 577 of carbonic acid, &c. In a similar manner, take any acid in the second column, the oxalic for instance; the first column shows how much of each base effects the saturation of 755 parts of oxalic acid, *viz.* 525 of alumine, 615 of magnesia, &c.

BASES.		ACIDS.	
Alumine	525	Fluoric	427
Magnesia	615	Carbonic	577
Ammonia	672	Sebacic	706
Lime	793	Muriatic	712
Soda	859	Oxalic	755
Strontites	1329	Phosphoric	979
Potash	1605	Formic	988
Barytes	2222	Sulphuric	1000
		Succinic	1209
		Nitric	1405
		Acetic	1480
		Citric	1563
		Tartaric	1691

No. IV.

I.—*Table, showing some of the Qualities of Metals ; the Proportion of Oxygen with which they combine ; and the Colours of their Oxides.*

(Compiled from two of the Tables in Thomson's Chemistry.)

Metals.	Colour.	Specific Grav.	Fusing Point.	No. of Oxides.	Colours of Oxides.	Prop. of Oxyg.
Gold	Yellow	19.361	32 W.	1 2	Purple Yellow	10.
Platina	White	23.000	+170 W.	1 2	Green Brown	.7½ 0.15
Palladium	White	11.871	+160 W.	1 2	Blue Yellow ?	
Rhodium	White	+11	+160 W.	1 2	 Yellow	
Iridium	White		+160 W.	1 2	Blue ? Red ?	
Osmium	Blue			1	Transparent	
Silver	White	10.510	22 W.	1 2	 Olive	 12.8
Mercury	White	13.568	— 39 F.	1 2 3	Black Red	5. 11.
Copper	Red	8.895	27 W.	1 2	Red Black	13. 25.
Iron	Blueish-grey	7.788	158 W.	1 2 3	White Black Red	29. 31.6 45.
Tin	White	7.299	442 F.	1 2	Grey White	25. 38.8
Lead	Blueish-white	11.352	612 F.	1 2 3 4	 Yellow Red Brown	 10.6 13.6 25.
Nickel	White	8.666	+160 W.	1 2	Green Black	28.

Table, showing some of the Qualities of Metals, &c.—continued.

Metals.	Colour.	Specific Grav.	Fusing Point.	No. of Oxides.	Colours of Oxides.	Prop. of Oxyg.
Zinc	White	6.861	680 F.	1 2	Ylow White	13.6 25.
Bismuth	White	9.822	476 F.	1 2	 Yellow	 12.
Antimony	Grey	6.712	809 F.	1 2	White Ditto	22.7 30.
Arsenic	White	8.310	+400 F.?	1 2	White White (acid)	33. 53.
Cobalt	White	7.700	130 W.	1 2 3	Bue Green Black	
Manganese	White	6.850	+160 W.	1 2 3	White Red Black	25. 35. 66.6
Molybdena	Grey	8.600	+170 W.	1 2 3 4	Light brown Violet Blue White	 34. 50.
Tellurium	White	6.115	+612 F.	1 2	White	
Tungsten	Greyish-white	17.6	+170 W.	1 2	Black Yellow	 25.
Uranium	Grey	9.000	+170 W.	1 2	Black Yellow	5.17 28.
Titanium	Red		+170 W.	1 2 3	Blue Red White	
Chromium	White		+170 W.	1 2 3	Green Brown Red	 200.
Columbium					White	
Tantalium					White	
Cerium	White			1 2	White Red	

N. B.—The numbers, in the last column of the foregoing table, denote the quantity of oxygen with which 100 parts of each metal combine. Thus, to form the black oxide of iron, 100 parts of the metal absorb 31.6 oxygen, and afford 131.6 of an oxide, which, in 100 parts, contains 24 of oxygen.—In the column showing the fusing point, W. added to the numerals denotes the degrees of Wedgwood's pyrometer, and F. those of Fahrenheit's thermometer.

II.—*Colour of the Precipitates thrown down from Metallic Solutions, by various Re-agents.*

Metals.	Prussiated Alkalis.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-Sulphurets.
Gold	Yellowish-white	Solution turned green. Precipitate brown of reduced gold	Yellow	Yellow
Platina	No precip.; but an orange coloured one by pruss. of mercur.	Dark green becoming paler	Precipitated in a metallic state	
Silver	White	Yellowish brown	Black	Black
Mercury	White, changing to yellow	Orange yellow	Black	Brownish black
Palladium	Olive,* Deep orange.†		Dark brown	Dark brown
Rhodium	No precip.			No precip.
Iridium	No precipitate. Colour discharged.	No precipitate. Colour of solutions discharged		
Osmium		Purple, changing to deep vivid blue		
Copper	Bright reddish brown	Brownish	Black	Black
Iron { 1.Green salts	White, changing to blue	No precipitate. Black	Not precipitated	Black
Iron { 2. Red salts	Deep blue			
Nickel	Green	Greyish white	Not precipitated	Black
Tin	White	No. precip.	Brown	Black

* Chenevix,   † Wollaston.

Colour of Precipitates from Metallic Solutions, &c.—continued.

Metals.	Prussiated Alkalis.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-Sulphurets.
Lead	White	White	Black	Black
Zinc	White	No. precip.	Yellow	White
Bismuth	White	Orange	Black	Black
Antimony	White	A white oxide merely from dilution.	Orange	Orange
Tellurium	No precip.	Yellow		Blackish
Arsenic	White	Little change	Yellow	Yellow
Cobalt	Brownish yellow	Yellowish white	Not precipitated	Black
Manganese	Yellowish white	No precip.	Not precipitated	White
Chrome	Green	Brown		Green
Molybdena	Brown	Deep brown	Brown	
Uranium	Brownish red	Chocolate		Brownish yellow
Tungsten				
Titanium	Grass green with a tinge of brown	Redish brown	Not precipitated	Grass green
Columbium	Olive	Orange		Chocolate
Tantalium				
Cerium		Yellowish		Brown, becoming deep green

Colour of Precipitates from Metallic Solutions, &c.—continued.

III.—*Table, showing the Maximum Quantity of Oxygen taken up by different Substances.*

SIMPLE COMBUSTIBLES.

100 Hydrogen unite with - -	597.7 Oxygen
100 Carbon - - - - -	257.
100 Azote - - - - -	236.
100 Muriatic acid - - - -	194.
100 Phosphorus - - - -	154.
100 Sulphur - - - - -	71.3

METALS.

100 Chrome combine with - -	200. Oxygen
100 Manganese - - - -	66.
100 Arsenic - - - - -	53.
100 Iron - - - - -	45.
100 Tin - - - - - -	38.8
100 Antimony - - - -	30.
100 Zinc	
100 Copper	
100 Lead	25.
100 Tungsten	
100 Mercury - - - - -	17.6
100 Platina - - - - -	15.
100 Silver - - - - -	12.8
100 Bismuth - - - - -	12.
100 Gold - - - - -	10.

No. V.

Table of Simple Affinity.*

	Iron	Sulphur	Sulphurous
OXYGEN.	Tin	Carbon	Acetic
	Uranium	Phosphorus	Mucic
Carbon	Molybdena	Nitrogen	Boracic
Charcoal	Tungsten		Nitrous
Manganese	Cobalt	———————	Carbonic
Zinc	Antimony		Prussic
Iron	Nickel	SULPHUR.	Oil
Tin	Arsenic	PHOSPHORUS ?	Water
Antimony	Chrome		Sulphur
Hydrogen	Bismuth	Potash	
Phosphorus	Lead	Soda	———————
Sulphur	Copper	Iron	
Arsenic	Tellurium	Copper	BARYTES.
Nitrogen	Platina	Tin	
Nickel	Mercury	Lead	Acids.Sulphuric
Cobalt	Silver	Silver	Oxalic
Copper	Gold	Bismuth	Succinic
Bismuth		Antimony	Fluoric
Caloric ?	———————	Mercury	Phosphoric
Mercury		Arsenic	Mucic
Silver	CARBON.	Molybdena	Nitric
Arsenous acid			Muriatic
Nitric oxide	Oxygen	———————	Suberic
Gold	Iron		Citric
Platina	Hydrogen		Tartaric
Carbonic oxide		POTASH, SODA,	Arsenic
Muriatic acid	———————	AND AMMONIA.	Lactic
White oxide of manganese	NITROGEN.		Benzoic
White oxide of lead	Oxygen	Acids.Sulphuric	Acetic
	Sulphur ?	Nitric	Boracic
	Phosphorus	Muriatic	Sulphurous
	Hydrogen	Phosphoric	Nitrous
———————		Fluoric	Carbonic
	———————	Oxalic	Prussic
OXYGEN.†		Tartaric	Sulphur
	HYDROGEN.	Arsenic	Phosphorus
Titanium		Succinic	Water
Manganese	Oxygen	Citric	Fixed Oils
Zinc		Lactic	
		Benzoic	

* This table, it may be necessary to observe, does not express accurately the *comparative affinities* of bodies, but denotes merely the actual *order of decomposition*, which, as Berthollet has shown, may often be contrary to that of affinity, owing to the influence of various extraneous forces.

† Vauquelin's table of the affinity of the metals for oxygen, according to the difficulty with which their oxides are decomposed by heat.

Table of Simple Affinity—Continued.

STRONTITES.	MAGNESIA.		Tartaric
		Carbonic	Citric
		Prussic	Lactic
Acids. Sulphuric	Acids. Oxalic		Succinic
Phosphoric	Phosphoric		Acetic
Oxalic	Sulphuric		Prussic
Tartaric	Fluoric	SILEX.	Carbonic
Fluoric	Arsenic		Ammonia
Nitric	Mucic	Fluoric acid	
Muriatic	Succinic	Potash	
Succinic	Nitric		
Acetic	Muriatic		OXIDE OF MER-CURY.
Arsenic	Tartaric	OX. OF PLATINA.	
Boracic	Citric	—— GOLD.*	
Carbonic	Malic ?		Gallic acid
Water	Lactic	Gallic acid	Muriatic
	Benzoic	Muriatic	Oxalic
	Acetic	Nitric	Succinic
	Boracic	Sulphuric	Arsenic
LIME.	Sulphurous	Arsenic	Phosphoric
	Nitrous	Fluoric	Sulphuric
Acids. Oxalic	Carbonic	Tartaric	Mucic
Sulphuric	Prussic	Phosphoric	Tartaric
Tartaric	Sulphur	Oxalic	Citric
Succinic		Citric	Malic
Phosphoric		Acetic	Sulphurous
Mucic		Succinic	Nitric
Nitric	ALUMINE.	Prussic	Fluoric
Muriatic		Carbonic	Acetic
Suberic	Acids. Sulphuric	Ammonia	Benzoic
Fluoric	Nitric		Boracic
Arsenic	Muriatic		Prussic
Lactic	Oxalic		Carbonic
Citric	Arsenic	OXIDE OF SIL-VER.	
Malic	Fluoric		
Benzoic	Tartaric		OXIDE OF LEAD.
Acetic	Succinic	Gallic acid	
Boracic	Mucic	Muriatic	Gallic
Sulphurous	Citric	Oxalic	Sulphuric
Nitrous	Phosphoric	Sulphuric	Mucic
Carbonic	Lactic	Mucic	Oxalic
Prussic	Benzoic	Phosphoric	Arsenic
Sulphur	Acetic	Sulphurous	Tartaric
Phosphorus	Boracic	Nitric	Phosphoric
Water	Sulphurous	Arsenic	Muriatic
Fixed oil	Nitrous	Fluoric	

* Omitting the oxalic, citric, succinic, and carbonic, and adding sulphu-retted hydrogen after ammonia.

Table of Simple Affinity—Continued.

Column 1

Sulphurous
Suberic
Nitric
Fluoric
Citric
Malic
Succinic
Lactic
Acetic
Benzoic
Boracic
Prussic
Carbonic
Fixed oils
Ammonia

OXIDE OF COPPER.
Gallic
Oxalic
Tartaric
Muriatic
Sulphuric
Mucic
Nitric
Arsenic
Phosphoric
Succinic
Fluoric
Citric
Lactic
Acetic
Boracic
Prussic
Carbonic
Fixed alkalis
Ammonia
Fixed oils

OXIDE OF ARSENIC.
Gallic

Column 2

Muriatic
Oxalic
Sulphuric
Nitric
Tartaric
Phosphoric
Fluoric
Succinic
Citric
Acetic
Prussic
Fixed alkalis
Ammonia
Fixed oils
Water

OXIDE OF IRON.
Gallic
Oxalic
Tartaric
Camphoric
Sulphuric
Mucic
Muriatic
Nitric
Phosphoric
Arsenic
Fluoric
Succinic
Citric
Lactic
Acetic
Boracic
Prussic
Carbonic

OXIDE OF TIN.*
Gallic
Muriatic
Sulphuric
Oxalic
Tartaric

Column 3

Arsenic
Phosphoric
Nitric
Succinic
Fluoric
Mucic
Citric
Lactic
Acetic
Boracic
Prussic
Ammonia

OXIDE OF ZINC.
Gallic
Oxalic
Sulphuric
Muriatic
Mucic
Nitric
Tartaric
Phosphoric
Citric
Succinic
Fluoric
Arsenic
Lactic
Acetic
Boracic
Prussic
Carbonic
Fixed alkalis
Ammonia

OXIDE OF ANTIMONY.
Gallic
Muriatic
Benzoic
Oxalic
Sulphuric
Nitric

Column 4

Tartaric
Mucic
Phosphoric
Citric
Succinic
Fluoric
Arsenic
Lactic
Acetic
Boracic
Prussic
Fixed alkalis
Ammonia

SULPHURIC ACID.
PRUSSIC.†
Barytes
Strontites
Potash
Soda
Lime
Magnesia
Ammonia
Glucine
Yttria
Alumine
Zircon
Metallic oxides

SULPHUROUS ACID.
SUCCINIC.‡
Barytes
Lime
Potash
Soda
Strontites
Magnesia
Ammonia
Glucine
Alumine

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* Bergman places the tartaric before the muriatic.
† With the omission of all after ammonia.
‡ Ammonia should come before magnesia; and strontites, glucine, and zircon, should be omitted.

Table of Simple Affinity—Continued.

Zircon	Potash	Magnesia	Soda
Metallic oxides	Soda	Metallic oxides	Barytes
	Strontites	Glucine	Ammonia
	Lime	Alumine	Alumine
PHOSPHORIC ACID.	Magnesia	Zircon	Magnesia
CARBONIC.*	Ammonia		
	Glucine		
Barytes	Alumine	OXALIC ACID.	FIXED OIL.
Strontites	Zircon	TARTARIC ——	
Lime	Metallic oxides	CITRIC ——.¶	Lime
Potash		Lime	Barytes
Soda		Barytes	Potash
Ammonia	FLUORIC ACID	Strontites	Soda
Magnesia	BORACIC ——‡	Magnesia	Magnesia
Glucine	ARSENIC ——||	Potash	Oxide of mercury
Alumine	TUNGSTIC ——	Soda	Other metallic oxides
Zircon	Lime	Ammonia	Alumine
Metallic oxides	Barytes	Alumine	
Silex	Strontites	Metallic oxides	
	Magnesia	Water	
	Potash	Alcohol	ALCOHOL.
PHOSPHOROUS ACID.	Soda		Water
	Ammonia		Ether
Lime	Glucine	BENZOIC ACID.	Volatile oil
Barytes	Alumine		Alkaline sulphurets
Strontites	Zircon	White oxide of arsenic	
Potash	Silex	Potash	
Soda		Soda	
Ammonia		Ammonia	SULPHURETTED HYDROGEN.
Glucine	ACETIC ACID.	Barytes	
Alumine	LACTIC ——	Lime	Barytes
Zircon	SUBERIC ——§	Magnesia	Potash
Metallic oxides	Barytes	Alumine	Soda
	Potash		Lime
NITRIC ACID	Soda		Ammonia
MURIATIC —.†	Strontites	CAMPHORIC ACID.	Magnesia
	Lime	Lime	Zircon
Barytes	Ammonia	Potash	

* Magnesia should stand above ammonia, and alumina and silicia should be omitted.

† Ammonia should stand above magnesia.

‡ Silex should be omitted, and, instead of it, water and alcohol be inserted.

|| Except silex

§ With the omission of strontites, metallic oxides, glucine, and zircon.

¶ Zircon after alumine.

POSTSCRIPT.

The printing of this work having been often delayed by my professional engagements, I am enabled to include in it a brief account of Mr. Davy's most recent discoveries. They are contained in a paper,* of which he has been so obliging as to send me a copy, and which will be published in the second part of the Philosophical Transactions for 1810.

According to the view, which had been commonly taken of the nature of muriatic and oxy-muriatic acids, the former is a simple body, and the latter a compound of that body with oxygen. Mr. Davy, from his earlier experiments, was led to modify in some degree this conclusion; and to consider the muriatic acid as a compound of a certain base with water, and the oxy-muriatic acid as a compound of the same base with oxygen. More lately, however, he has been induced by the experiments of Gay Lussac and Thenard, as well as by some of his own, made expressly for the purpose, to take a very different view of the subject. Oxy-muriatic acid he now regards as a simple or undecompounded basis; and muriatic acid as a compound of that basis with hydrogen. The facts, which are the ground work of this inference, fall chiefly under two classes: 1stly, Muriatic acid, it is alleged, can in no instance be procured from oxy-muriatic acid, without the presence either of hydrogen, or of some body capable of affording hydrogen. 2dly, When oxy-muriatic acid combines with metals or other oxidizable substances, it is contended, we have no proof, from an examination of the results, that any oxygen has been furnished to the combustible body.

Of the first class of facts the most singular is that charcoal, ignited to whiteness in oxy-muriatic acid, effects no change in it. This might be explained on either of two suppositions; *viz.* that oxy-muriatic contains no oxygen; or that the oxygen, which enters into its composition, is held by a stronger affinity than that with which charcoal attracts it. Now there are several facts which show that, under certain circumstances, the affinity of charcoal for

* Entitled "Researches on the Oxy-muriatic Acid, its Nature and Combinations; and on the Elements of Muriatic Acid, with some Experiments on Sulphur and Phosphorus."

oxygen is surpassed even by that of hydrogen. The experiment, therefore, does not decisively prove, that no oxygen is present in oxy-muriatic acid. In a subsequent part of the paper, Mr. Davy states that no decomposition of oxy-muriatic acid can be effected by electricity, a fact certainly confirming the notion of its being a simple substance.

On investigating the nature of the compounds, formed by the oxy-muriatic acid and metals, Mr. Davy was led to examine, with particular attention, that which results from the action of oxy-muriatic acid on tin. When these bodies are brought into contact, the whole of the gas is absorbed by the metal. On the commonly received theory, therefore, that the oxidation of a metal invariably precedes its solution, an oxide of tin might be looked for in the new compound; but, by the most careful experiments, Mr. Davy was not able to discover any.

Again, when oxy-muriatic acid is made to act on phosphorus, *phosphorous* or *phosphoric acid* ought to be generated; and as the latter acid is fixed in a strong heat, it might be expected to remain after igniting the product. Mr. Davy, however, found that the new compound, when saturated with ammonia, and afterwards made red-hot out of the contact of air, yielded no gaseous product whatsoever (a very singular circumstance when we consider the volatility of its ingredients.) He observed, also, that the residue manifested no traces of phosphoric acid, unless it had been previously heated in the atmosphere, and had undergone a sort of combustion.

If oxygen enter into the constitution of oxy-muriatic acid, it follows that water should be formed by its action on ammonia; and this indeed has been commonly stated to be the fact. But Mr. Davy, on repeating the process with the view of deciding this point, was not able to discover that any water was generated.

In an experiment originally made by Mr. Cruickshank, oxy-muriatic acid and hydrogen gases were found to unite after some time by simple admixture: and a condensible matter remained, which was nothing more than muriatic acid. This fact is equally well explained in two different ways; for we may either suppose that the hydrogen unites with oxygen furnished by the oxy-muriatic acid, and sets at liberty muriatic acid pre-existing in that compound; or else that the hydrogen unites with the oxy-muriatic acid, which in this view is a simple body, and that the two united form common muriatic acid. The latter explanation is the one which Mr. Davy prefers, chiefly because the presence of oxygen

in oxy-muriatic acid has not been demonstrated by other experiments.

When potassium is ignited in muriatic acid gas, hydrogen is evolved, and muriate of potash remains. But even this salt Mr. Davy is disposed to regard not as a compound of oxide of potassium (potash) with muriatic acid, but as a compound of metallic potassium with oxy-muriatic acid. In all cases, indeed, where muriatic acid gas is acted on by metals, he supposes that the oxy-muriatic acid is attracted from hydrogen by the metal, and a real oxy-muriate generated.

The vivid combustion of inflammable bodies in oxy-muriatic acid gas Mr. Davy does not admit to be a valid objection to his theory. The evolution of heat and light he deems to be no proof of oxygenation, but to arise merely from that intensity of action, which attends various combinations where the fixation of oxygen has never been suspected.

The compounds termed *hyper-oxymuriates*, which have been considered, chiefly on the suggestion of Mr. Chenevix, as containing oxy-muriatic acid united with an additional dose of oxygen, are rather, according to Mr. Davy's theory, compounds of oxy-muriatic acid with metallic oxides. Hyper-oxymuriate of potash, for example, is oxide of potassium saturated with oxy-muriatic acid, or a triple compound of oxy-muriatic acid, potassium, and oxygen; while muriate of potash is metallic potassium saturated with oxy-muriatic acid.

In this view of the subject, oxy-muriatic acid performs the same functions as oxygen. With respect to its electrical habitudes, it may be arranged in the same class with that basis; and in all analyses of its compounds by galvanic electricity, oxy-muriatic acid is evolved at the positive and hydrogen at the negative surface. In strictness, it can scarcely be deemed an acid, but rather a sort of acidifying principle.

If these striking and ingenious speculations (for such they must at present be regarded) should be confirmed by future experimental researches, material changes will be required in the existing nomenclature of chemistry; and important modifications must be made in several parts of the received theory of the science.

Another subject, to which Mr. Davy has recently directed his attention, is the action of potassium on sulphur and sulphuretted hydrogen, and on phosphorus and phosphuretted hydrogen. If potassium and sulphur be made to act on each other in glass retorts, part of the potassium, he finds, is lost by its operation on the

glass. This furnishes one reason why less sulphuretted hydrogen gas was evolved in Mr. Davy's former experiments, from a given weight of potassium combined with sulphur, than might have been expected from the quantity of hydrogen evolved by the recent metal. On repeating the experiment, no proof was gained that the potassium had acquired oxygen from the sulphur. All that can be demonstrated is a combination of potassium with sulphur, in the proportion of three of the former to one of the latter, which burns into neutral sulphate of potash. Neither did it appear that by the action of potassium on phosphorus, any effect was produced beyond the formation of a phosphuret of potassium, consisting of about three parts of phosphorus to eight of the metal.

It is remarkable that the weights of the ultimate atoms of several compounds, deduced by Mr. Davy from his own experiments, do not differ very materially from those which had been inferred by Mr. Dalton from other data. This will appear from a comparison of the following numbers with those already stated at page 328 of this volume.

The weight of an ultimate atom of potash - - - 48.
———————————————— potassium - - 40.5
———————————————— oxy-muriatic acid - 32.9
———————————————— muriatic acid - 33.9
———————————————— phosphorus - - 16.5
———————————————— sulphur - - 13.5

NOTES,

BY PROFESSOR SILLIMAN, OF YALE COLLEGE.

Note 32, page 8. Natural History of Metals.

THE metals are not presented immediately to the hand of man, like the objects of the animal and vegetable kingdoms, but, they are, for the most part, buried in darkness, in the bowels of the earth, where they are so much disguised, by combination and mixture with other substances, that they often appear entirely unlike themselves. Hence they are acquired only by slow and painful toil, and by noxious processes, and dangerous operations; their properties and uses have been but slowly developed, and it is to be regretted, that they are the most usual instruments of human destruction, and, because they are more or less the representatives of all other kinds of property, they have been made the immediate motives, means and objects, of the most sordid passions and the most flagitious crimes.

The metals are occasionally found, in nature, in the metallic state, but, more generally, they are combined with other substances, and, in this state, they are called *ores*. A metal, in this condition, is said to be mineralized, and the substance with which it is combined, is called the mineralizer. The principal mineralizers are oxygen, sulphur, arsenic, the carbonic, sulphuric, muriatic, arsenic and phosphoric acids, and carbon. As far as our knowledge at present extends, all ores may be included under one or another of the following descriptions :

1. Native metals, and alloys of one metal with another.
2. Native metallic oxides ; or, compounds of the metals with oxygen.
3. Native metallic salts; or, compounds of the metallic oxides with acids.
4. Native sulphurets and carburets ; or, compounds of the metals with sulphur or carbon.

Gold, silver, platina, mercury, copper, bismuth, antimony and arsenic are frequently found native ;—iron more rarely, and a few other metals have been reported to be found occasionally native. The native alloys exist principally btween gold and silver, gold and copper, and mercury and silver. Arsenic, however, is a very common mineralizer, and exists, more or less, in a great proportion of the ores. Platina is always found in the metallic state ;—gold, most generally, and silver frequently.

The metallic oxides and sulphurets constitute by far the most extensive and important classes of ores. In the state of oxide the metals are brittle, " have an earthy appearance and exhibit different colours, but have no lustre. Iron, cobalt, copper, arsenic, bismuth, antimony, zinc, manganese, tin, lead and mercury exist in this condition." (Schmeisser ii. 14.)

Metals, combined with sulphur, are also brittle, but they frequently have the metallic lustre. The compounds of iron and sulphur are called pyrites;

the same name is applied to compounds of sulphur and iron, containing copper, or arsenic, and the first description is called ferruginous—the second cupreous, and the third arsenical pyrites.

Heat produces in the sulphurets a sulphureous odour, and in those which contain arsenic, as many of the pyritical ores do, an odour of garlic is produced by friction, percussion and heat. Silver, iron, lead, copper, mercury and antimony are often found combined with sulphur. (Ibid.)

The only metal whose combination with carbon is well understood is iron, in the substance called plumbago.

The compounds of acids with metallic oxides are more rare than most of the preceding states; they appear differently, and some of them look much more like earthy substances than ores.

1. Iron is found combined with the sulphuric, phosphoric and carbonic acids, &c.

2. Copper with the sulphuric, carbonic, arsenic and muriatic acids, &c.

3. Lead with the sulphuric, carbonic, arsenic, chromic, molybdic and muriatic acids, &c.

4. Zinc with the sulphuric.

5. Antimony with the muriatic.

6. Silver with the sulphuric, muriatic and arsenic acids.

7. Mercury with the sulphuric and muriatic acids.

8. Cobalt with the arsenic and sulphuric acids.

9. Manganese with the carbonic and phosphoric acids.

The ores constitute but a very small portion of this globe, at least of those parts of it which have been explored. They are never found in large extended masses, like those of granite, trap and limestone, but, usually, in cavities and veins, principally in the hardest rocks. These are often divided by fissures, running through them in various directions, the two sides of which frequently tally to each other as if they had been divided by some convulsion of the globe. It is in such fissures that the veins of metal are commonly found. They usually cross the strata at right angles, and, in most instances, are perpendicular or inclined to the horizon; rarely are they horizontal. The veins do not consist entirely of ore; the greater portion of them is, for the most part, filled with some kind of stony substance different from the rock; it is commonly denominated spar, because it has often a crystalline or plated structure. Carbonate of lime, or calcareous spar, fluor spar or fluate of lime, quartz, amorphous and crystallized, and sulphate of barytes, or, ponderous spar, are the most frequent, and the latter more so than perhaps any other. The miners call these things the matrix or gangue of the particular metal; sometimes the metal is dispersed among the gangue only in specks; at other times it prevails so as to occupy a considerable part, or nearly the whole of the vein. Although ores are sometimes found in horizontal beds, in plain countries, they are most abundant in mountainous and rugged regions. Granite and the other primitive rocks rarely contain ores, but gneiss and the schistose rocks contain them in abundance; limestone, quartz and barytic spars are well stored with them; they are not abundant in whin, and serpentine very seldom affords them.

There are perhaps few subjects on which mankind are more credulous than

on that of the discovery of ores. Hence the numerous impositions practised on the ignorant and avaricious by artful and impudent knavery. It is now scarcely credible that implicit faith was once reposed in the *virgula divinitoria*, or divining rod as it was called, nor should we have expected that the British Encyclopedia would have more than countenanced a folly which the good sense of mankind has long since discarded. Mr. Price, an English writer on the Cornish mines, has very gravely informed us that; "hazle rods cut in the winter do best," and that "apple tree suckers, rods from peach trees, currants, or the oak, will answer tolerably well."—The use of these rods was, that, when poised in a particular manner in the hand, they would be attracted toward the spot of earth containing an ore. Mr. Price says that if a person with a divining rod in his hand stand with one foot advanced and a guinea beneath it, and a half-penny beneath the other foot, the rod will be drawn towards the guinea, and that if the guinea be put into the place of the half-penny, the attractions will be reversed. This art once formed a distinct profession, and the same impostors pretended to be affected with convulsions, swoonings, lethargy, &c. when reposing on ground beneath which metals lay concealed. It would hardly be proper to mention such ridiculous follies, were there not still some people in this country who have a strong leaning toward them. Much more confidence is reposed in certain indications almost equally fallacious, such as the dreary aspect of a mountain—the sterility and nakedness of a country—the blighted state of vegetation, imaginary exhalations from the ground, and many other similar things. But, when metallic grains and fragments are found dispersed among the sand of a plain, or in the bed of a river, it is reasonably concluded that they have been detached by rains from the hills, and washed down by the water; when the springs of a country are contaminated with a metalline impregnation, there can be no doubt that ores are below. Above all, when a vein of metal appears at the surface, which not unfrequently happens on the steep side of a hill, a promontory, or the bank of a river, decisive evidence is obtained.

The fortunes of men ought not to be hazarded in mining speculations without all the certainty that the nature of the case will admit of, and this can frequently be afforded by *boring*, a simple and not very expensive operation, which is worth more than all the divinations and enchantments that have ever been practised.

MINE AND MINING.

After the existence of ore is ascertained to the satisfaction of the adventurers, if the country be level, or nearly so, a pit similar to a well is sunk; it is called a shaft, and if the earth be not sufficiently compact, the sides of the shaft are supported by planks and timbers; timbers are placed horizontally also, at convenient distances, and, upon these, ladders are firmly fixed in a perpendicular position, and a plank or two laid at the foot of each for a landing place; as the shaft goes down deeper and deeper, other ladders are added, in a connected series, till the miners arrive at the ore. Having found it, they of course follow the vein; this produces another excavation, at right angles with the shaft; it is called an adit, level, or gallery. If the

mine be worked through a rock, there are, of course, natural walls, and a roof sufficiently firm; sometimes the walls of the vein are of rock, while the roof is crumbly, and it must then be supported firmly by planks and timber. As the only inducement to excavate the gallery arises from the width of the vein, the gallery varies extremely in diameter;—at one place, where the vein has failed, or become very small, it is merely a narrow passage, where the miners can do nothing more than crawl through;—at another, a man can walk erect with ease, and, at another, it becomes a wide and lofty chamber. Sometimes the gallery is intersected by another vein running off at an angle; here a new gallery may be formed, and thus the work may be indefinitely extended. A shaft is often sunk from the gallery already formed, to meet a new one below, and thus these subterranean passages are made to communicate freely with one another, and with the surface of the ground. When the mine is situated in a hilly country, it becomes easy to discharge the water, merely by continuing the galleries out, to the side of a hill; but, in a level country, the water must be raised to the surface. For this purpose, as well as for raising the ore, letting down people and implements, and for other similar objects, all the powers of mechanism are occasionally employed.

The strength of men and of animals; mills, worked by wind or water, and, above all, the steam engine, which is in general use in England, are employed to accomplish the desired object. In the Dolgoath mine in Cornwall, a steam engine is employed to raise the water. The machine there employed works a rod composed of pieces of timber; it descends more than 1000 feet into the ground, and raises the water to a superior adit, where it runs off through the side of the hill. There is another evil to which the miner is peculiarly exposed. Deadly gases, consisting chiefly of the carbonic acid gas, and some varieties of the hydrogen gases, occasionally suffocate him; and, when they are inflammable, which often happens in coal mines, they become mixed with the atmospherical oxygen; when the miners descend with lamps and candles to their work, the mixture sometimes explodes and blows the adventurers and their works into the air, or hurries them with fatal velocity along the narrow chambers of the mine. To prevent these evils, recourse is had to ventilation. When the mine is situated in the side of a hill, and the galleries are continued out to the side, a ventilation is, of course, established, because the mouth of the shaft and the outlet of the gallery are at different elevations; the air within the shaft is in winter warmer, and, in summer, colder than that above ground; thus, the two columns of air, the one of which presses at the mouth of the gallery, and the other at the bottom of the shaft, are *rarely* in equilibrio, and therefore a current is established one way or the other. It is observed, that about the equinoxes, these columns sometimes are so nearly in equipoise, (because the air without and within the earth is then very nearly of the same temperature) that the miners perceive a stagnation, and it becomes necessary to kindle a fire in order to destroy the equilibrium. When circumstances do not admit of a natural ventilation, as where shafts have been sunk in a level country, it is accomplished by maintaining at the mouth of one of the shafts a constant fire, which discharges its heated air through a

long chimney, and thus the equilibrium of the otherwise equiponderant columns of the atmosphere is destroyed, and a double current of foul air up, and of good air down is maintained. No work can be done in the mines without artificial light, which enables the miner to see where the vein is richest in ore, and there he applies his hammers, crows, levers, pick axes, wedges, and other mechanical instruments to detach it from the rock. If, however, this be very hard, it is necessary to employ the force of gun powder; indeed this is more generally necessary, and the explosions (from their happening prematurely, or from their driving fragments of the rock to a distance, and thus hitting those who imagined themselves out of danger) are not unfrequently fatal to the workmen. The great copper mine of Dolgoath, at Redruth, in Cornwall, is a fair example to illustrate most of the particulars mentioned in this sketch.

Much labour and expense are saved when the ore is so situated that direct access can be had to it by a lateral excavation in the side of a hill or mountain. Then it is necessary only to penetrate into the ground in a horizontal direction till the ore is found, and thus the same passage, which serves as an entrance, affords also a drain for the water, a gallery for the people to go in and out, and a road for the conveyance of the ore, which is transported to day light on small hand sleds or waggons, drawn along the bottom of the adit; frequently, the miners are *harnessed* to these simple machines, as they find, from experience, that they work with more ease in this way. It is not possible, however, to penetrate far into a mountain without ventilation. In pursuing the narrow passage of the gallery, the air becomes so much vitiated by the respiration of the workmen, and by the burning of their candles, that, ultimately, their lights begin to burn dimly, their breathing becomes laborious, and every thing announces imminent danger. To obviate this, either a shaft is sunk from a higher part of the hill to meet the adit, or another gallery is made at a different elevation, and the two are connected in the interior of the mountain by a shaft, and thus a ventilation is produced upon the principles already explained. In this description of mines, all the expensive and troublesome machinery calculated to raise the ore and the water, and to let down people, implements, &c. may be dispensed with, and the business is wonderfully simplified.

Of this kind of mines, the ancient and celebrated ore at Castleton, in Derbyshire, called the Owdin mine, is a fine example.

Metallurgy.

As a preliminary to the great and expensive processes for extracting metals from their ores in the large way, it is necessary to perform the same thing on a small scale, for the purpose of forming a judgement as to the profit which may be expected from the mine, and, indeed, this step ought always to be taken previously to the expenditure of any great sums in the mechanical operations of mining, otherwise, great loss may be sustained. These operations are called *docimasy* or the *docimastic* art; they constitute the assay, by which the quality and richness of the ore is judged of. The habit of examining minerals will soon enable a person, from the external appearance of an ore, to form a tolerably correct judgement of its nature and value.

The blow-pipe will prove an important aid to his judgement, for, by means of this, assisted by proper fluxes, a judgement can usually be formed, in a few minutes, as to the kind of ore, although not always as to the proportion of metal. A piece of charcoal or a spoon of platina is commonly used for a support to the bit of ore under examination, and various additions of borax—sub carbonate of soda—black or white flux, microcosmic salt, &c. are made according to the object in view. The blow-pipe is admirably adapted to the almost instantaneous production of a high and very manageable heat. As examples of its use, it may be mentioned that if a minute portion of the ore of cobalt be fused with borax, a fine blue button will be formed; if the proportion of salt has been too small, the button will appear almost black, but will become blue, on being diluted with more borax and fused over again. If borax be fused with oxide of manganese, a purple button will be formed; if this button be completely surrounded by the flame of the blow-pipe, and urged with a heat continued, for a few minutes, the globule will emit bubbles of gas and will become colourless; this is owing to the escape of oxygen gas which brings the manganese to the state of white oxide when it loses its colour. If this colourless globule be heated again with the exterior flame of the blow-pipe, while the air has free contact with the globule, the purple colour will return; then by alternately repeating the first and second experiment upon it, the colour may be discharged and renewed at pleasure. Should these circumstances occur, the operator would, with good reason, conclude, that the first substance was cobalt and the second manganese. For minute instructions as to the use of the blow-pipe, reference may be had to Bergman's chemistry.

For practical purposes, the examination of ores is, however, commonly made in the assay furnace. Good, middling and poor specimens of the ore are selected, that the result may be neither too flattering nor too discouraging. The pieces selected should be as free from the matrix as possible, and the stony matter may be still farther separated by breaking it with a hammer.

The ore is then pounded and the stony matters farther picked out; and advantage is taken of the difference in specific gravity between the ore and the matrix; they are agitated in water, or a stream is suffered to pass over them, when the metallic parts will sink and the stony fragments are washed away. A convenient quantity is then taken, varying from 100 grains to 100 pounds, according to the nature and value of the ore, and the degree of precision required; this is roasted, as it is called, that is, it is exposed, for a considerable time, to a low red heat, applied in shallow vessels. The object of this operation is to expel any sulphur or arsenic, which the mineral may contain; and which it is, may be inferred from the smell, which is sulphureous in the one case, and alliaceous in the other. During this operation the metal is always converted into an oxide, and the object of the next process is to bring it to the state of a metal, by mixing it with substances which will at once promote its fusion, and abstract its oxygen. These substances are called fluxes; they are numerous and various, and different fluxes are employed in reducing different ores, but they usually contain carbon, as one ingredient, and some saline or alkaline substance; the former to abstract

oxygen and the latter to promote fusion. The most common is the black flux, formed from two parts of tartar and 1 of nitre, mixed in a red hot crucible; this is well adapted to the ores of lead, copper and antimony. Another flux, well adapted to iron ores, is composed of 20 parts of calcined borax, 10 of nitre and 2 of slacked lime, and these proportions correspond to 10 grains of the ore. Pounded glass 16 parts, borax 2, and powder of charcoal 1, answer the same purpose. Arsenic and nitre, in equal parts, form also a very active flux. With some of these, or other fluxes, a certain quantity of the roasted ore is heated in a crucible, and, at the end of the operation, the metal is found reduced, at the bottom of the crucible, forming a metallic button, whose weight, compared with that of the ore, gives the proportion of metal with sufficient accuracy to enable those concerned to decide on the expediency of prosecuting the adventure. This is however but a coarse analysis, if the object be to ascertain with correctness, the true chemical composition of the ore. But, in an economical point of view, it is, perhaps, even preferable to the more accurate methods, because it is of importance that the assay should, as much possible, resemble the metallurgic processes in the large way, which must, necessarily, be performed with cheap materials and in a coarse manner, because the expense would absorb the profits were the costly re-agents of scientific chemistry introduced into the smelting and refining furnaces.

This method of examination is *via sicca*, in the dry way, as it used to be called. But, if we would ascertain the true composition of the ore, so as to give the specimen its correct place in a system of scientific mineralogy, we must have recourse to the analysis, *via humida*, or, in the moist way, that is, not by fire, but by acids, alkalis and other re-agents. This method is now universally preferred by expert chemists, where science and not profit, is the object. Its processes however are tedious and require the utmost skill and patience in the analyst, and absolute purity in his re-agents. An account of them involves details which would be misplaced among these general remarks, and more properly belong to the history of the particular metals.

After what has been said as to the manner of assaying ores, it will not be necessary to be very minute upon the operations of metallurgy in the large way, since the principles are almost identical, and the variations in the processes are produced chiefly by a reference to economy and facility of operation. The more general operations to which the ore is subjected, are *sorting, stamping, washing, reducing* and *refining*.

The sorting is merely the *picking over* of the ore, to free it from the matrix and other foreign bodies. In common cases it is entrusted to women and children, but if there be several ores intermixed, which it is necessary to separate, especially if any of them be very valuable, as gold or silver, the sorting is then performed by skilful men, superintended by a master miner, or captain of the mines.

The object of the *stamping* is to reduce the ore to moderately small fragments, in order to facilitate the farther separation of the matrix. For this purpose, it is pounded in stamping mills. They consist of perpendicular cylindrical pieces of wood, shod at the foot with iron, and worked by wind

or water, or some other adequate moving power, which causes these great pestles to play up and down in huge stone troughs or mortars, containing the ore, while, in many instances, a stream of water, passing through the trough, washes away the lighter stony parts. The ore is always washed or dressed for the purpose of separating the stony fragments, and there are many ingenious means of doing this, as in the bed of a rivulet, on an artificial inclined plain, over which water is made to pass; in tubs, boxes, &c. When there are grains, or minute fragments of very valuable metal, as for instance gold, dispersed among sand, the washing is performed on inclined plains, covered with cloth, which catches the angular and small pieces, that would otherwise be washed away. When the stony matrix is very hard, it is sometimes rendered friable by heating it and throwing it, while very hot, into water, which causes it to crack.

The next object is the *roasting*. This is commonly performed in the open air, the ore being mixed with heaps of wood and exposed to a gentle red heat, a good while continued. Sometimes this operation is performed among charcoal, in furnaces of a particular form, contrived to save the arsenic or the sulphur as the case may be; they rise, in sublimation, and are condensed in some proper receptacle. Nitre is sometimes used to burn out the sulphur, but is too expensive for common use. Some ores require several repetitions of the process of roasting before they are cleared of their sulphur and arsenic.

REDUCTION is the next and most important operation of the whole, to which the others may be regarded as merely preparatory. This is done in furnaces which vary exceedingly in size and form, according to the particular nature of the metal and the practice of different countries.

The great object is now to separate the oxygen, that the metal may appear in its proper character. For this purpose the ore is mixed with large quantities of fuel, commonly charcoal or oak, and a strong heat is raised; the remaining sulphur and arsenic are expelled, and the oxygen, combining with the red hot carbon, flies away in the form of carbonic acid gas and gaseous oxide of carbon. Appropriate fluxes are also added to fuse any earthy matters which may remain, and sometimes lime and alkali, and even some of the less valuable metals are added to absorb the sulphur more completely. At length the metal, freed from most of its impurities, subsides to the bottom of the furnace, and the earthy and sulphurated mass floats as a scum or slag. This is sometimes drawn off at a convenient tap hole, or by rakes, or blown aside by the blast of bellows. The melted metal itself is drawn off by a tap hole at the bottom of the furnace, or, when the quantity is small, it is dipped out with ladles. The slag or scum is not always rejected. Sometimes it is rich in some other metal, which, during the operation, has been oxidized and scorified, while that which was the principal object of the process, on account of its different nature, has not suffered the same change. The slag is therefore *occasionally*, and, in some particular cases, *usually* worked over by itself, and frequently yields no contemptible product. Sometimes it is is very valuable of itself, as in the extraction of silver from lead ores, where the oxidized lead forms a slag which is the foundation of the manufacturers of litharge and red lead.

When volatile metals are to be obtained from their ores, it becomes necessary to employ a distilling apparatus, as retorts of earth or iron; mercury and zinc are metals of this description.

The metals which have been obtained by the processes of reduction, although usually sufficiently pure for commercial purposes, are rarely so in a chemical sense; they are occasionally contaminated with some of the earthy matters with which the ore has been treated, and they are often alloyed with other metals, some of which may be more valuable than the whole mass, or which impair the proper qualities of the metal.

Last of all then comes the process of REFINING, the object of which is to obtain the metal absolutely pure, or at least sufficiently so to answer all the purposes for which it is wanted. As, however, the processes for refining differ exceedingly, in the cases of the different metals, it is scarcely possible to give any general account of the subject. Such details belong more properly to the history of the particular metals.

The number of the metals is now nearly thirty. Most of them are of modern discovery. The ancients were acquainted with only seven, viz. gold, silver, mercury, iron, lead, tin and copper.

Note 33, page 35. Silver.

The remark in the text, that silver, when dissolved in nitric acid exhibits a green colour if impure, is strictly applicable to the alloy of silver with copper, such as exists in coin and in trinkets, which, when dissolved in nitric acid, tinge the solution green, but silver might be impure from a combination with various other substances, without giving, on that account, a green solution. It often happens also during the action of nitric acid on metals, that a temporary green solution is obtained, owing to the generation of nitrous gas, and its transient combination with the solution; if the green colour is owing to this cause, it will disappear if the solution be heated.

Note 34, page 39. Fulminating Silver.

Pulverize 100 grains of the common lunar caustic of the shops (nitrate of silver;) add to it one ounce of alcohol and one ounce of nitric acid. If these agents are good, there will be a violent action. But this will not happen with these fluids as they are commonly found, and generally it will be necessary to apply a very moderate heat, which must be removed as soon as the action comes on. Very soon a thick white precipitate will appear; distilled water may then be thrown on to check the action if becoming too violent; the precipitate must be washed in distilled water, after having been separated by the filter, or by decantation, and will fulminate powerfully by heat or friction. A convenient way of exploding it is to place a grain or two of it on the blade of a knife, and to hold it over a candle. This process I believe was substantially suggested by Descotils, and the fulminating silver produced in this manner is, compared with that of Berthollet, a harmless preparation. Still, it is sufficiently critical and violent to render great care necessary in its preparation. Having been, for several years, accustomed to prepare it, and having never met with any accident, I had probably come, by degrees, to undervalue the danger, and, in conse-

quence incurred a serious injury, which had well nigh deprived me of my eyes; the mention of the manner in which it occurred, may perhaps save some person from a similar accident. The usual mixture of lunar caustic, alcohol and nitric acid, being made in a porcelain dish, I ventured to take it up and stir it with a glass rod, to accelerate the action, which was rather languid, and as no mischief happened from this step, which I had never ventured on before, I stirred it again, and, as some part of the nitrate adhered to the dish, a little pressure was used to detach it, when the whole exploded into my eyes with great violence, and threw me into immediate blindness, both from the mechanical force of the explosion, and from the corrosive action of the chemical agents. After some weeks of suffering and darkness, my sight was gradually restored, although the strength of the organs has never been fully regained. I have prepared the fulminating silver repeatedly since, without any accident. (For a more particular account, see Bruce's Journal, Vol. I. page 163.)

Note 35, page 61. Sulphuret of Iron.

There can be no doubt that the author perfectly understood that the phenomenon of the extrication of latent caloric, attended by light, during the combination of sulphur and iron, is not, as he has termed it, a *combustion*. Were it a real combustion, the iron would be found oxidized, and the sulphur acidified. But neither of these facts is so. It is well known that the compound decomposes water by the aid of an acid, and sulphur rises dissolved in the hydrogen, both of which facts are inconsistent with a previous combustion. Whatever uncertainty there may be (and it is acknowledged there is much) in the use of the word combustion, it must, no doubt, in every case, include a combination of oxygen with the body burned, and an increase of weight in the sum of the products, neither of which facts exists in this case.

Note 36, page 65.

METEORIC STONES.

The falling of stones from the atmosphere, is now universally admitted, not only by philosophical men, but, such a mass of evidence has been accumulated on the subject, that both the knowledge and belief of these events have become general.

The phenomenon is usually connected with the appearance of luminous meteors, or fire balls. Their apparent diameter is sometimes as large as the moon;* "from the main body, frequently extends a flame or train. Streams and sparkles of fire seem to shoot out on every side. Just before their disappearance, there is a violent explosion, by which pieces often appear to be detached, and thrown to the ground."

"When the stones have fallen in the *day* time, the meteor has not always been observed; probably, because its light was not sufficiently strong to draw the attention of persons abroad, to that part of the heavens, in which it was moving. But, even in this case, the same kind of *report* has

* See Professor Day's view of theories on this subject. (Memoirs of Connecticut Academy, Vol. I. Part I. page 164.)

been heard, as that which usually follows the explosion of a meteor. In many instances, the luminous body has been seen to come forward to the zenith, and apparently to burst; and, immediately after, the stones have fallen, with a whizzing noise, to the ground."

Meteors of this kind are seen, in some parts of the world, almost every year, and the same meteor is often seen over a great extent of country; in some instances, a hundred miles in breadth, and five hundred in length. (Day's view.)

Their perpendicular altitude during the time in which they are visible is calculated to be from 20 to 100 miles; and their diameter is, in some cases, estimated to be at least half a mile.

Their velocity cannot be less than 300 miles in a minute.

It has not been ascertained that these meteors do, in every instance, project stones to the ground; but stones have been observed to descend in so many instances immediately after the explosion of meteors, as sufficiently to establish the point that the stones do proceed from the meteor, and it may be presumed that, in numerous instances, they have fallen into the water, or other inaccessible places, or been effectually concealed, by being buried in the ground, in consequence of the violence of their descent.

The number of well authenticated instances in which stones have fallen from the atmosphere is now so great, that instead of attempting to enumerate them all, we shall make a selection of the most important only.

There have been traditionary and historical accounts of the falling of bodies from the heavens, from very remote antiquity. Sometimes they were regarded as objects of idolatrous worship; such was the το διοπετους (or that which fell down from Jupiter) of the Ephesians.

Livy mentions a shower of stones at Rome, under Tullus Hostilius, and a similar event is recorded to have happened there under the Consuls C. Martius and M. Torquatus. Pliny mentions a shower of iron in Lucania, the year before the defeat of Crassus, and that a very large stone fell in Thrace, in the 78th Olympiad, and three large stones are asserted to have fallen in the same country, about 452 years before Christ.* These and other similar assertions in ancient history were uniformly regarded, by the moderns, as instances of falsehood, or of excessive credulity and superstition; but they are now treated with more respect, and little doubt remains in the minds of men of science, that stones have fallen in every age of the world.

On the 7th of June, 1492, a large stone, weighing 260 pounds, fell at Ensisheim, in Upper Alsace, in France; it was preserved, till within a few years past, in a church, and was regarded as a sacred object. It fell in a storm, when the heavens appeared to be on fire, and after a loud report like a clap of thunder.

About 120 stones, among which was one of 120 and another of 60 pounds weight, fell near Padua, in the year 1510.

In 1627, the great astronomer Gassendi saw a burning stone of 59 pounds fall on Mount Vaiser, near the city of Nice, in France.

* Many of the facts stated in this abstract are taken from a table drawn up by Mr. Izarn, and which may be found in the Phil. Mag. XV. 162, and Thomson's Chemistry, second edition, Vol. III. page 419.

In 1706, a stone of 72 pounds fell, near Sarissa, in Macedonia.

In 1750, a stony mass fell at Niort, in Normandy.

In July, 1753, there was a shower of stones at Plann, near Tabor, in Bohemia; and, in September, two stones, weighing 20 pounds, fell at Siponas, in Bresse; and still another instance occurred in the same year, in the Eichstadt country, in Germany. A labourer at a brick kiln, when the ground was covered with snow, saw a body fall immediately after a violent report like thunder. He ran to the spot, but the stone still retained so much heat, that it could not be handled. It was about six inches in diameter.

In 1762, two stones, of 200 and 300 pounds, fell near Verona.

"On the 13th of September, 1768, a tempestuous cloud was seen near the castle of Sucé, in Main. From this was heard an explosion like thunder; but, without the appearance of lightning, and, directly after, a remarkable whizzing noise in the air. A number of travellers, looking up, saw an opake body descend in a curve line, and fall at a distance from them. They all ran to the place, and found a kind of stone half buried in the ground, and too hot to be touched." (Professor Day's Discourse.)

In the same year a stone fell at Aire, in Artois, and another at Le Cotentin.

A shower of stones fell at Barboutan, near Roquefort, in July 1789.

July 24, 1790, there was an extensive shower of stones in the environs of Agen.*

June 16, 1794, about 7 o'clock, P. M. at Sienna, in Italy, a tremendous cloud came from the north, sending forth sparks like a rocket, burning, and smoking like a furnace, producing violent explosions, and casting down stones to the ground. The cloud was very high. The stones, which were about twelve in number, fell at the feet of several persons.

December 13, 1795, near the Wold Cottage, in Yorkshire, England, unusual noises, like distant reports of pistols or guns, and also a *whizzing*, were heard in the air; there was no thunder or lightning. A labourer saw a body descend and strike the ground; several persons went immediately to the spot, and found an extraordinary stone, weighing 56 pounds, buried 21 inches in the earth. It was warm, smoked, and smelt strongly of sulphur.

February 19, 1796, a stone of 10 pounds fell in Portugal.

March 12, 1798, one of 20 pounds fell at Sales, near Ville Franche, and, on the 17th of the same month and year, another, of the same weight, at Salé, Department of the Rhone.

December 19, (same year,) about 8 o'clock, in a clear serene evening, a large fire ball was seen at Benares, in Bengal; it was attended by a loud noise like thunder, or a discharge of musquetry, and a shower of stones fell in a neighbouring field, and buried themselves about 6 inches deep.

April 26, 1802, about 1 o'clock, P. M. near L'Aigle, in Normandy, a very brilliant fiery globe was seen to move very rapidly through the atmosphere. Immediately after, a violent explosion, which lasted five or six

* A stone is preserved in the museum of Bordeaux, which, in 1789 or 1790, fell through the roof of a cottage, and killed a herdsman and some cattle.

minutes, was heard at the distance of 30 leagues, in every direction from L'Aigle. The sky was serene and calm, and there were only a few light clouds. A shower of stones fell in various parts of a district 7 miles in length, and 2 or 3 in breadth; the largest stone weighed 17 pounds, and the whole number was thought to be two or three thousand. One of them (presented by Col. Gibbs,) is preserved in the cabinet of Yale College.

One of the most remarkable occurrences of the kind on record happened at Weston, in Connecticut, on the 14th of December, 1807. Just after the dawn, a luminous meteor, or fire ball, apparently one half or two thirds as large as the moon, rose from the horizon in the north, and proceeded with great velocity, and a waving motion, nearly to the zenith; it was distinctly visible, through the clouds which partly covered the sky, appearing like the sun in a mist, and, when it passed the spots of clear sky, it flashed, with a vivid light, on the beholders, sparkled like a fire brand carried rapidly against the wind, discovered a waving conical train or tail of paler light; and, at length, with three loud and distinct explosions, like those of cannon, with as many leaps, and a rapid succession of fainter reports, like those of musketry, and a decay of light somewhat gradual, disappeared. This meteor was seen from Vermont to the city of New-York, and over an extent of two or three hundred miles from New-Jersey, to Salem in Massachusetts. Masses of stone were projected from it, at each of the three principal explosions; they were scattered over an extent of ten miles in length, and three or four in breadth. One mass fell within a few yards of a man who was standing at his door; it was dashed to pieces on a rock; a piece as large as a goose egg remained unbroken, and was warm half an hour after the fall. A stone of 35 pounds fell in a door yard within a few feet of the house; it buried itself completely in the ground, at the depth of two feet. Two other stones, one of about 8 or 10 pounds, and the other of 13 pounds, fell in the fields near the same house. Two miles south, two other stones fell, one at the foot of Tashowa hill, and the other upon it; the former weighed about 20 pounds, and the latter 36 1-2 pounds; they made deep holes in the ground. At the last explosion, a mass of stone was projected, which must have weighed at least 200 pounds; it descended with a roaring noise, and a visible curve of light; struck a rock with a great concussion, dashed it, and was itself dashed in pieces, tearing a hole in the ground, on to which it glanced, of 5 feet long, 3 feet deep, and 4 1-2 wide. In all the instances there was a whizzing or roaring noise in the air, when the stones descended, and an evident concussion of the ground, when they struck. All the most important facts were witnessed by numbers of people, who never before heard of the falling of stones from the atmosphere.

Since this event, a large stone of between one and two hundred pounds weight has fallen in Russia, and, on the whole, there is much reason to believe that similar events occur almost every year, and probably have occurred from the remotest ages.

There is such a wonderful similarity in the appearance and composition of these stones, that they are completely different from any other, and yet so similar to one another, that they are readily recognized by the eye of

even a careless observer. Those which have fallen in the remotest countries, in the East Indies, in Europe, and America, are almost precisely alike in their external appearance, and chemical constitution.

Where they have not been too much broken to admit of its being observed, they are covered externally with a black crust, rough like shagreen, and proceeding, in all probability, from the effects of heat, in producing an oxygenizement and vitrification of the metallic and earthy substances. In their form, they are irregular, but they often exhibit spherical and commonly curvilinear figures. When they first fall, they often smell of sulphur, and are found to be hot if immediately examined. When broken, four distinct sorts or forms of substances may be discovered in them, either by the naked eye, or by the microscope.

1. Globular and spherical bodies, of a dark brown, or gray colour, hard enough to scratch glass, and to give a few faint sparks with steel; easily breaking under the hammer, and of a compact texture. They are of every size, from that of a grain of sand, to that of a pea. They lie imbedded in the mass of stone which appears generally of an ash gray, or light slate colour.

2. There are numerous and often highly brilliant points of pyrites of a redish yellow colour, very friable, and, when powdered, appearing black.

3. Portions of iron in the metallic state, dispersed promiscuously, like the pyrites, through the stone, and varying in size, from mere points to the magnitude of an inch or more.

4. The basis of the whole stone, that which connects all the other substances, and from which they may be detached by the point of a knife, is a granular earthy matter of an ash-gray colour, often inclining to slate, easily pulverized by the hammer and pestle, and, when in small pieces, without much difficulty between the fingers. There is, of course, a considerable variety in the distribution and proportion of the constituent substance, in the earthy cement, and, when it has been wet, spots of iron rust often appear upon the surface. The specific gravity varies from 3.352 to 4.281.

In the stones which fell at Weston, there was a considerable variety in the appearance of the earthy cement; some parts of it were light coloured, almost white, and of regular forms, as if those parts had once been a crystallized substance. In the composition of these stones there is such a surprising coincidence, as, in connection with their physical characters, and the phenomena which attend their appearance, must render it in the highest degree probable that they have a similar origin. According to Mr. Howard, a stone, which fell at Benares, consisted, in its different parts, of the following ingredients:

The pyrites contained,
{ 2.0 sulphur,
10.5 iron,
1.0 nickel,
2.0 earths, and foreign bodies.

15.5

The spherical bodies, $\begin{cases} 50.0 \text{ silex,} \\ 15.0 \text{ magnesia,} \\ 34.0 \text{ oxide of iron,} \\ 2.5 \text{ oxide of nickel.} \end{cases}$

———

107.5

The earthy cement, $\begin{cases} 48.0 \text{ silex,} \\ 18.0 \text{ magnesia,} \\ 34.0 \text{ oxide of iron,} \\ 2.5 \text{ oxide of nickel.} \end{cases}$

The stone of Yorkshire, when deprived as much as possible of metallic masses, gave Mr. Howard the following proportions in 150 grains :

75 silex,
37 magnesia,
48 oxide of iron,
2 oxide of nickel.

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The increase of weight was occasioned by the addition of oxygen to the metals.

The stones of L'Aigle yielded to Vauquelin and Fourcroy :

54 silex,
36 oxide of iron,
9 magnesia,
3 oxide of nickel,
2 sulphur,
1 lime.

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105

The stone of Ensisheim gave the same analysts :

56.0 silex,
30.0 oxide of iron,
12.0 magnesia,
2.4 nickel,
3.5 sulphur,
1.4 lime.

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105.3

The stones which fell at Weston, in 1807, gave, according to my analysis,

51.5 silex,
38. oxide of iron,
13. magnesia,
1.5 oxide of nickel,
1. sulphur.

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Thus we see that the stones consist, invariably, of silex, iron, magnesia, nickel, and sulphur ; the silex constitutes generally about one half;—the

iron from a quarter to a third, and sometimes more ; the magnesia from a tenth to a sixth, and that the sulphur and nickel are in very small proportion.

The lime mentioned in two of the analyses is probably accidental, and the existence of chrome has been asserted by Laugier, but this has not been confirmed by other chemists.

As to the origin of these bodies, the subject is involved in such obscurity that no satisfactory *conjecture*, not to say hypothesis or theory, has been as yet advanced. There is, however, some difference in the degrees of improbability, attached to them respectively. All that deserve any attention may be included under the following heads :

1. The meteoric stones are formed in the atmosphere.
2. They are thrown from the volcanoes of this earth.
3. They are ejected from those of the moon.
4. They are thrown from terrestrial comets.

The mere existence of so many hypotheses is sufficient to prove, that we have no real knowledge on the subject. A few remarks on each of these suppositions will suffice to show that it is much more easy to raise objections than to substitute a satisfactory explanation.

1. As to the atmospheric formation of these bodies. Of the ingredients found in these stones, sulphur is the only one ever known to be in the state of vapour, and the proportion of this found in the various meteoric stones that have been analysed, is extremely small. Silex and magnesia are not only not volatilizable, but they are nearly infusible ; iron and nickel require the most violent degrees of heat to become fluid, and probably can never have more than a momentary existence in the state of vapour, even in the most powerful furnaces. How is it possible then that these substances should get into the atmosphere in the state of vapour or gas, and, if possible, why have they never been found in the air when it has been analysed ?

Since the discovery of Mr. Davy that several of the earths have very combustible metallic bases, he has suggested that these bases may come into the atmosphere in a metallic state, and there take fire ; but, if the decomposition of silex had been satisfactorily effected, which it has not, still this explanation would be embarrassed with difficulties which must attend the theory of the atmospheric formation of the meteoric stones, even allowing it possible for the materials of which they are composed to exist in the air, in the state of vapour or gas.

Should they combine in the air, is it credible that they would rush from great distances to one point, and there form a large solid body ; would they not rather be precipitated in small masses or flakes like snow or hail? Hail is never precipitated in masses weighing hundreds of pounds ; on the contrary, hail stones do not often exceed a few ounces in weight, and we have every reason to suppose that the region in which they are formed is often filled with aqueous vapour, where corpuscular attraction, could it ever exert such an extensive agency upon aeriform particles would produce a great aggregation of matter. These difficulties are much increased, when we consider that some of the meteors from which the stones have

descended, have been hundreds and sometimes thousands of feet in circumference; this is admitted by the best astronomers and philosophers, and is capable of being satisfactorily shown from deductions drawn from their apparent diameter, and the time that has elapsed between the extinction of the luminary at the explosion, and the arrival of the sound to the ear of the observer.

But, even waving all these difficulties, how could these meteoric bodies acquire their prodigious horizontal velocity? If formed in the air, they would descend rapidly in lines perpendicular to the horizon; but their motion is nearly horizontal, and it could not be communicated by the air; for, " the progress of the most violent wind is not more than two or three miles in a minute—but a meteor moves several hundred—the velocity of sound is less than 1200 feet in a second, that of a meteor more than 20,000 —the greatest force of gunpowder will throw a cannon ball but a very few miles, while a meteor is often seen to move several hundred." Other objections might be urged against this theory, but these are sufficient to prove that it is untenable.

2. Their origin from terrestrial volcanoes is still more improbable. The composition and appearance of the stones is different from that of any known volcanic substances; the stones have fallen hundreds and even thousands of miles from volcanoes; distances to which it is impossible that they should be conveyed, by any force that can be exerted at the surface of the earth, and when it is considered that the stones which have come down to us are merely minute portions, torn off from the great meteoric bodies, which have continued to move on after the rupture, and had they fallen, would have been of sufficient size in some instances, to have filled the craters of the largest volcanoes, this theory must be regarded as inadmissible, and, indeed, at the present time, I believe it has no advocates.

We are not assuming one theory to oppose another, for, luminous meteors, which have apparently exploded, and been extinguished, at the moment when atmospheric stones have fallen, have appeared in so large a proportion of the instances that are best attested, and most minutely described, that, notwithstanding some cases have occurred where the stones have apparently proceeded from burning clouds, and no fiery globe has been observed, still these appearances were probably the effect of optical illusion, or of the presence of the sun's light, and we are sufficiently authorised to conclude that atmospheric stones proceed from luminous meteors passing rapidly through the air, and no theory can be satisfactory which does not account for both.

3. Their ejection from lunar volcanoes, although supported by one of the most distinguished of the French philosophers, and countenanced probably by a majority of the men of science in Europe, appears to be hardly more tenable than the two preceding theories. It is admitted to be possible, that if a body were thrown from the moon with a force of about ten thousand feet in a second, it might pass the point of equal attraction, which is about twenty-four thousand miles from the moon's centre, and, then, if the earth and moon were relatively at rest, it would come in a right line to the earth's surface; but, as the moon and earth are both

moving forward in their respective orbits, the path described by a body projected from the moon would be a curve, the result of the composition of the motion of the moon in her orbit, the projectile force, and the power of gravitation, and the body would therefore probably revolve around the earth ; if by any means pieces were detached from it, they would fall to the earth, and thus the theory appears to be possible, if we take into view only those insignificant portions of the meteoric bodies which come to the earth. Philosophers seem to have employed themselves principally in accounting for these, without taking into consideration that they are mere atoms of the bodies from which they have come. The body of a meteor is a firm compact substance, for no other could preserve the correct globular form in moving so rapidly through the atmosphere ; and their light is usually well defined, so that hundreds and thousands of people who have seen them at once, give substantially the same account as to their apparent magnitude ; hence there is good reason to conclude, that the estimates which have been made of their magnitudes have not been much overrated. Dr. Herschell estimates the altitude of the lunar mountains as being generally not more than half a mile ; now is it credible, that bodies whose diameter is from two or three hundred feet to half a mile, should be projected from lunar volcanoes, and with such force as to go beyond the common centre of attraction, and arrive in the atmosphere of the earth ? Indeed, if it may be permitted seriously to combat so extravagant a supposition, would not the re-action upon the moon itself produce a violent explosion of her own sphere, as a gun is burst by an over charge. We do not know the composition of the moon, and it may, for ought we know, be uniformly composed of silex, iron, magnesia, sulphur, and nickel, but this is in the highest degree improbable ; yet as the meteoric stones are all of similar composition, the theory implies this, while we know that the lavas and other volcanic matters of our own earth are composed of the most various ingredients, and are often very dissimilar from each other.

Probably, not a year elapses without a meteor's being seen in some part of the world, and, had they been of lunar origin, no small part of that satellite would, ere this, have been shot off in meteors.

4. Their origin from terrestrial comets, is the only one of the theories which remains to be considered. That the earth may be attended by a system of inferior satellites corresponding to the solar comets, has been frequently suggested by philosophers ; but we are indebted to the Rev. Thomas Clap, formerly president of Yale College, for an elaborate consideration, and a minute application of it to the explanation of the phenomena of meteors. This gentleman left behind him a paper containing " Conjectures on the nature and motion of Meteors." It was considered by its author as an unfinished treatise, but it was published some years after his decease, and although it does not appear that the learned author was acquainted with the falling of stones from the atmosphere, (for this subject had not then attracted the attention of philosophers,) this circumstance, instead of invalidating his theory, would have brought a great accession of strength to its support.

President Clap had it in view merely to account for the fire balls usually denominated meteors.

The explanation was founded upon an analogy drawn from the solar comets—particularly, from the eccentricity of their orbits, their consequent near approach to the sun in their perihelion, their prodigious distance at their aphelion, and the long course of time, in some instances hundreds of years, which they take to accomplish their revolutions. "President Clap supposed (see Professor Day's VIEW) that the earth is furnished with its system of comets, as well as the sun—that their size, and the period of their revolutions are proportioned to the comparative smallness of the primary body, about which they revolve—that, like the solar comets, they move off in very elliptical orbits; and, during the greatest part of their circuit, are too far distant to be visible—that, in their approach to the earth, they fall within our atmosphere—that, by the friction of the air, they are heated, and highly electrified—that the electricity is discharged with a very violent report—that they then move off in their orbits, and, by their great velocity, are soon carried out of our sight."

The appearance of the meteors is such as corresponds very well with this view of the subject.

The dimensions of these bodies, the rapidity of their motion, the direction of their course, the proportion which they bear in size to their central body the earth, being about the same as the little planets, recently discovered between the orbits of Mars and Jupiter, have to the sun, about which they revolve, all accord perfectly well with the supposition of planetary bodies moving through the lower part of their orbits, and not at all with what might be expected from matter falling from condensed gases or vapours, or projected from lunar or terrestrial volcanoes.

It is calculated, that if a body, moving horizontally near the earth, have a velocity of less than 300 miles in a minute, it must fall to the earth—if of more than 430, it will, if undisturbed by other bodies, fly of in an hyperbola, and will never return.

Adequate allowance being made for the resistance of the air, and the motion of the earth, a body will, within these limits, revolve around the earth in an ellipsis, and return at regular periods.

Now, it is very remarkable that the velocity of such meteors as have been observed is generally rather more than 300 miles in a minute, that is, just enough to carry them clear of the earth and yet so small as to bring them within its atmosphere, while moving through the lower parts of their orbits.

Granting the existence of these bodies, and, that their motion is such as has been described, it is easy to see that any cause which might produce a rupture or explosion of a part of their substance, might, very naturally, throw fragments to the ground, and the circumstances which have, in numerous instances, actually attended *their descent* ;—its rapidity, proved by the holes which they make in the earth, the whizzing or roaring noise, and the violent concussion; its *irregularity*, the fragments being scattered over several miles of territory, which is what we might expect from the effects of a violent explosion ; its happening immediately after explosions actually

heard from the fire ball and after the extinction of its light, and the minute proportion which the fragments bear to the whole body of the meteor;—all these circumstances considered together cannot leave a doubt that in numerous instances, at least, the stones have been thrown off from a large solid body moving rapidly through the atmosphere. But, the stones bear no sensible proportion to the whole meteoric mass, and this must be supposed to move on in its orbit, scarcely disturbed by the trifling loss which it has sustained, and no longer luminous, because the heat aud electricity have been, in a great measure, dissipated by the explosion.

There is nothing inconsistent with analogy in supposing the existence of numerous small planetary bodies in the solar system; they may be necessary to adjust the balances of motion and attraction, and they may well enough be of an uniform and sterile composition, since no analogy would lead us to suppose them inhabited, or even habitable. This conjecture derives confirmation from the discovery within a few years past, of several very small planets, in the solar system, where they had never been suspected before.

Upon this view of the subject, it is highly probable that meteoric stones have fallen, in every age of the world, and that this phenomenon will frequently occur again.

The theory of president Clap, with the addition which has now been stated, appears to be liable to only two objections, of much importance.

It may be said, that it does not account for such appearances as that of Sienna, and a few similar ones, where the stones have seemed to proceed from a burning cloud. Under such circumstances of terror and amazement, there is much room for optical deception, and perhaps we are not justified in concluding, that a meteor may not illuminate a cloud, by which it is in part concealed.

The other objection is founded on the apparent inadequacy of the cause assigned by president Clap, for the ignition of the meteors; it remains yet to be proved, that mere friction with the air is sufficient to produce strong ignition in a solid body, or to excite electricity enough to generate that effect, and the attendant explosion.

The explosion might however be owing, not merely to an electrical discharge, but also to the expansive force of vapour and gases, suddenly and powerfully rarefied by heat.

With these qualifications, the origin of meteoric stones seems to be better explained upon this, than upon any other scheme, but, as yet it can be regarded only in the light of an hypothesis, recommended by the felicity with which it explains most of the phenomena. Should one of the meteors ever approach the earth, without sufficient projectile force to carry it clear of our planet; its fall would be inevitable, and those philosophers who are so happy as to witness such a catastrophe, uninjured, will have better means than we now possess, for constructing a satisfactory theory on this obscure, but highly interesting subject.

AUTHORITIES FOR THE PRECEDING STATEMENTS.

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Note 37, page 110.   Gallic Acid.

The due regulation of the heat is very important in this method of obtaining gallic acid. A moderate sand-heat is sufficient, and the retort must be removed from the fire at the moment when a dark coloured oil begins to rise, or before, because this oil will redissolve, or greatly contaminate the crystals of gallic acid.

Note 38, page 149.   Congelation of Alcohol.

The congelation of alcohol was mentioned in a former note; it is to be regretted that we are not able to give the process by which this was effected; this, if published at all, it is believed has not yet reached this country. There are, however, a few facts relative to the appearances attending the congelation, which are worthy of notice. The alcohol was prepared according to Richter's process, and was of the specific gravity .798 at 62°; it was enclosed in a thermometer tube, in which it was congealed. This was afterwards effected in a tube sealed at one end and open at the other; the alcohol was so far congealed, that on inverting the tube, only a very minute stream of fluid glided down the inside of the tube, and, eventually, the solid alcohol fell out into a glass, was broken into several pieces, and quickly melted; in subsequent experiments the alcohol was so completely solidified, that no portion of it remained fluid. It was found that solid masses of alcohol could be soldered together;—in the paradoxical language of the discoverer, (Mr. Hutton of Edinburgh,) "a rod of frozen mercury or sometimes a straw cooled down to a very low temperature," was used as "a hot-bath" for the purpose of fusing the frozen alcohol so as to admit of its being soldered. Mr. Hutton remarked that the alcohol crystallized, and that it sometimes separated into three very distinct strata; the uppermost was of a pale yellowish green, while the second was of a very pale yellow colour: both these strata were very thin, the last mentioned was rather the thickest; the lowermost stratum was nearly transparent, and colourless, and very greatly exceeded the other two in quantity." In order to ascertain whether these appearances arose from a decomposition of the alcohol, Mr. Hutton mingled the results of several processes, such as have been described, and heated them to about 120° by means of a water bath, by which means a perfect alcohol was reproduced. He therefore concluded that these appearances were owing to impurities, which accounted also for a difference in the forms of the crystals which had been obscured in different experiments. Mr. Hutton concludes that

the lowermost stratum contains the true alcohol, and that the other two contain, chiefly, volatile impurities, which can be separated only by freezing, and that it is to these that the alcohol owes its peculiar flavour.

Note 39, page 220. *On the Artificial Preparation of Mineral Waters.*

It is only within the last half century, that a correct knowledge of the nature of mineral waters has been obtained. Their utility in a variety of diseases has been proved by the uniform experience of mankind from remote ages; even savage nations know that there is a very great diversity in the qualities and effects of different natural waters, and they are accustomed to make use of them for not a few of the same purposes that we do. The most powerful and celebrated mineral spring of this country, was known to the Indians in its vicinity, and they first pointed it out to the white people. Before the composition of mineral waters was understood, their efficacy was imputed in a great degree, to a supposed fermentation in the bowels of the earth and to some volatile principles, too subtile to be detected by the art of man. The notions concerning them were visionary and fanciful, and bordered, not a little, on superstition.

It is not the least, among the attainments of modern chemistry, that more correct views of this subject have been acquired, and that the exact analysis of all the most celebrated natural mineral waters has led the way to their artificial formation, upon principles of science and common sense.

To the illustrious Bergman we are indebted for some of the earliest practical researches, and most useful directions on this subject. He analysed, with accuracy, several of the famous waters of Germany, and having discovered their contents, he applied himself with such ardour and success to effect their recomposition, that in a short time, the prepared waters were introduced into the remotest provinces of Sweden. The dissertations of Bergman on these subjects should be carefully perused by all who are engaged in these pursuits.

Strictly speaking, all waters except rain and snow, and distilled waters are mineral; because they all contain, in a greater or less degree, mineral substances dissolved in them; even rain and snow water are not perfectly pure, and it may be doubted whether water ever is, unless distilled in glass vessels, for, water which has been condensed by the pewter worm of a common still gives a precipitate with sulphuretted hydrogen. In most natural springs and rivers, however, the proportion of foreign matter is so minute, as not materially to affect their sensible or chemical properties, and, it is only when this is the case that the term *mineral* is, with propriety, applied to a water.

Although there is a very great variety in the degree and nature of the impregnation of different waters, they are commonly included under a few general divisions, according to the kind and proportion of the ingredients which they contain.

They are either, 1. SALINE; 2. CHALYBEATE 3. ACIDULOUS; or, 4. HEPATIC; the first, distinguished by the prevalence of saline ingredients, the second by iron, the third by carbonic acid, and the fourth by sulphuretted hydrogen. This division is rather loose, as these classes are often

more or less mixed with one another, and there are a few substances of more rare occurrence, that are not included under either of them. It may serve, however, as a guide in designating the principal varieties of operation that are necessary in forming the different sorts of mineral waters. It is almost superfluous to remark that a correct knowledge of the constitution of a mineral water must be attained before we can hope to succeed in preparing it artificially, and, the chemist must either perform the analysis for himself, or confide in that of some other person.

I. OF SALINE WATERS. The artificial preparation of this class of waters is the most simple and easy, although their analysis is often the most complicated and difficult. All that is necessary is merely to weigh out the different salts, in the proper proportions, and dissolve them in the water.

Some of these salts are sold regularly in the shops of the apothecaries. Such are the sulphate of soda, (Glauber's salt) the sulphate of magnesia, (Epsom salt) the carbonate of soda, (sal soda) &c. The muriate of soda, (common salt) is in every family. Sometimes these salts are sufficiently pure to be employed without any farther trouble, but, more generally, it will be necessary to redissolve and crystallize them anew.

There are some salts which are denominated *incompatible*, because they cannot exist in the same solution without mutual decomposition ; such are muriate of magnesia and carbonate of soda ; were a solution of each of these salts to be mingled, there would be an immediate precipitation of carbonate of magnesia ; and muriate of soda, alone, would remain in solution. Should any analyst imagine that he had discovered such salts in contemporaneous existence in a mineral water, he must of course conclude that his analysis is erroneous, and therefore, in any attempt to form an artificial water, he will be careful not to mingle any such inconsistent ingredients.

Some salts are not to be found in the shops, and therefore must be prepared on purpose. Such are muriate of lime and muriate of magnesia.—It is best to prepare these salts by adding the carbonates of lime and magnesia to muriatic acid diluted with one or two parts of water. For the former, marble powder should be used, formed by pounding in a clean mortar very white marble, and, if the powder have been previously exposed to a full red heat, till as much carbonic acid has been expelled as can be driven off in that way, it will dissolve with much more facility. Chalk may be used, but this is apt to produce a very frothy and troublesome effervescence, unless the acid is largely diluted, when the action will be slow ; the same remarks are applicable to the carbonate of magnesia.—As the muriates of these two bases are very deliquescent and difficult to be crystallized, and, as they are prone, when very much concentrated, to become gelatinous, it is convenient to keep them in the fluid form, in close stopped bottles. A small portion may be measured out ; for instance, two gills, and evaporated to dryness, and the residuum weighed ; this will inform us how much solid salt is contained in any measured portion of the solution, and thus, much trouble may be saved, as the salts may be introduced into the water in the fluid form. There are a few salts occasionally found in mineral waters, which it may be adviseable not to intro-

duce. Such is the sulphate of lime; it does not possess any known medical efficacy, and it may be deposited in the system and create serious obstructions. For similar reasons, it is even doubtful whether the carbonate of lime ought to be added to artificial waters, at least in the proportion in which it is often found in native mineral waters; for, as it is dissolved in them only by the aid of the carbonic acid *in excess*, it follows that, when this acid, by the warmth of the system, is expelled from the water, in the course of its circulation, the carbonate of lime may be deposited in some of the cavities and prove a troublesome impediment; especially in the kidneys, the gall bladder or urinary bladder, and the ducts connected with them. The carbonate of magnesia is liable to be affected in a similar way, and, although these carbonates are, both, good correctors of acidity, and, in that way, useful in mineral waters, they may not always meet with an acid in the passages, which they may neutralize, and by which they may be carried off; if they should not meet an acid in the system, they would probably be deposited. Besides, their place, as antacids, is much more than supplied by carbonate of soda which is liable to none of these objections. In the composition of some mineral waters, it may therefore be adviseable to omit some of the ingredients and even to substitute others; for, we are not to presume that the substances which a mineral water has chanced to dissolve in its progress among the strata, are necessarily such, either in kind or proportion, as are best adapted to cure diseases, and therefore, it is clearly possible that a water of great utility may be formed without imitating any native mineral water. Such experiments however, ought to be directed by medical as well as chemical science.

Among the salts which have been discovered in mineral waters, the carbonates of lime, magnesia and iron;—the sulphates of soda, magnesia and lime; the muriates of soda, lime and magnesia, and the hydro-sulphuret of lime are the most common, and they are those with which we have most to do in the preparation of artificial mineral waters. Iron is almost the only metal of much importance found in waters; copper occurs, but more rarely, and it is not often that waters impregnated with it are used medicinally, as it is so poisonous to all animals.

II. CHALYBEATE WATERS. Iron gives the character to this species of waters, and it is almost always suspended in them by the carbonic acid; it, sometimes, occurs combined with the sulphuric acid, but this fact is so rare that chalybeate waters are generally acidulous and sparkling, and sometimes they are very highly charged with the carbonic acid. The method of making a water chalybeate is simply this: very pure and clean iron, in the state of filings, is to be introduced, in the proper proportion, into water charged, or immediately to be charged, with carbonic acid; the iron will be oxidized, in the lower degree, by the water, and then will be dissolved by the carbonic acid, and the more highly the water is charged with this acid gas the more rapidly and in the greater proportion will it dissolve the iron. In estimating the proportion of the iron to be added to the water, we must allow only so much as, when combined with the oxygen and carbonic acid will equal the weight of carbonate of iron found, by analysis, in the water which we would imitate. A small quantity of iron imparts to water such decided

properties that it is necessary to be very attentive to the proportion of iron. If the iron be in the higher state of oxygenizement, *it will not dissolve in the water* impregnated with carbonic acid, and if, after solution by this acid, it be exposed to the atmosphere, the carbonic acid will principally escape ; the iron will pass to the state of red oxide, and will be precipitated, a mere rust, and the chalybeate will thus be decomposed. It is therefore, for both these reasons, indispensable, that artificial chalybeate waters be prepared and kept in air-tight vessels. It is for the same reason that Bergman recommends introducing the iron filings in a small bag, and directs that when the bag is removed from the mineral water vessel, it should be immediately plunged into clean water, by which means it will be kept from passing to the state of red oxide ; for, the rusting of iron in common cases, is effected by the joint action of water and the atmospherical oxygen. The method recommended by Bergman of introducing an indefinite quantity of iron filings in a bag, I have found by experience not to be so good, as to put in the exact quantity of iron that is wanted, for more gives the water too high a chalybeate impregnation, and it is apt to become turbid, and to have a very disagreeable odour, like hydrogen, and, indeed, this smell probably proceeds from hydrogen, condensed in the water during its decomposition by the iron, for the chalybeate waters are prone to have something of this odour. In some artificial chalybeate waters *sulphate of iron* is introduced instead of combining the iron in the manner that I have described. This is a great error, and, no person will ever, in that way, succeed in imitating the native carbonated chalybeate waters. The taste and other sensible properties, as well as the medical effects are very different. Whether an artificial chalybeate has been impregnated with the sulphate or carbonate of iron, may be easily decided by the same process which is applied to natural waters of these descriptions : viz. heat the water for a short time ; if it is a carbonate, the iron will speedily be deposited, in the form of a rust, and the water will no longer give the well known precipitates with the prussiate of potash and with gallic acid. But, if a sulphate of iron be present, there will be little or no deposite during the heating, and the fluid will answer to the above mentioned tests as well as before. When water is highly impregnated with carbonic acid, it acquires the chalybeate taste and other properties very rapidly ; the iron can be tasted within half an hour, after it is introduced, and twelve hours will produce a decided impregnation. Chalybeate waters are often more or less saline ; indeed they are usually so, and some of them are strongly impregnated with salts. There is no imcompatibility between the carbonate of iron and the salts most commonly found in chalybeate springs ; it frequently exists in company with the earthy carbonates and sometimes even with the carbonate of soda. In forming a saline chalybeate, nothing more is necessary than to mix the salts, in the proper proportions, with the water, then to add the iron, and then inject the carbonic acid without delay, and to the intended extent.

III. ACIDULOUS WATERS. This is a highly interesting class of mineral waters, whose nature was entirely unknown till the discovery of carbonic acid assimilated them with the brisk fermented liquors, such as Champaigne wine, porter, cider, perry, &c. which owe their grateful pungency and

briskness to the same cause. There is a very great difference in the proportion of carbonic acid existing in different mineral waters; even common water contains a small portion, and there are mineral springs which are impregnated with two or even three times their bulk of this acid gas. It is the introduction of this gas which forms the most difficult and laborious part of the business of preparing artificial mineral waters. It is in this department, particularly, that modern improvements have attained a degree of excellence surpassing all previous conception, and producing results which have demonstrated that art can sometimes transcend the productions of nature.

Those who have not the means of doing better, may still practise the ingenious, although simple, processes of Bergman. The water to be impregnated with the carbonic acid may be introduced into a bottle, which should be quite full, and inverted in a proper vessel; carbonic acid, from a mixture of marble powder and dilute sulphuric acid, may then be passed up into the bottle, till about one third of the water is displaced; then, one hand being slid under the bottle's mouth, and the other placed upon its bottom, the bottle must be briskly agitated; an absorption will take place, the hand will be pressed fast to the bottle's mouth, it should be withdrawn under water, a portion of which will rush in to supply the void, and a repetition of this operation, will soon saturate the water as far as it can be at the given temperature, and under the given pressure of the atmosphere. The water, thus impregnated, will have a mildly pungent and acidulous taste, and will sparkle when poured into a tumbler. The colder the water is, the more gas will be absorbed. If it is wished to add any saline ingredients; that can be done either before or after the impregnation with carbonic acid; and iron may be added to make it a chalybeate; for the acidulous waters are usually both chalybeate and saline. Although, by the means which have just been described, water can be impregnated as highly as it commonly is, in the natural acidulous waters, the impregnation may be carried much farther by peculiar contrivances and maniplations. I do not allude to the apparatus of Nooth or Priestly, which, although elegant and showy, and sufficiently powerful for the experimental illustrations of a lecture, is altogether improper for operations on a large scale and where it is desired to apply a great degree of force to effect the combination. The principal means by which water is charged with the amazing quantities of carbonic acid gas which are, now, introduced into it, may be reduced to three heads.

1. PRESSURE. 2. COLD. 3. AGITATION.—All these are combined in the most perfect manufactories of mineral waters, and some observations will be necessary on each of these heads.

1. PRESSURE. This is applied by means of strong forcing pumps which may be worked either by hand alone, by the hands aided by a lever, by a wheel, by coggs and cranks, or any other convenient mechanical power, and if the strength of men be not sufficient, that of horses may be applied, and even water, wind, and steam may be called in to our aid. This is however, by no means necessary. A strong man, after becoming accustomed to the exertion, will inject as much gas as will impart to the waters a degree

of activity far surpassing any thing which they ever possess in nature. As this impregnation depends entirely on the pressure which is applied to the gas to force it into union with the water, it is obvious that the containing vessels must possess a degree of strength proportioned to the force which is to be applied. Glass is entirely improper, however thick, and apparently strong, because an explosion, which is no uncommon accident in these operations, would be attended with the most hazardous consequences. The vessels must therefore be made of wood or metal. Very strong casks of oak, made of the very best timber, and constructed in the most careful manner, are the most proper instruments, if we regard, primarily, the purity of the waters and the health of those who use them. The casks must be very strongly bound and guarded with iron hoops and strong iron bars in every direction; they must be furnished with an internal apparatus for agitation, or they must rotate on an axis to effect the same object. Their strength must be such that they will not strain so as to produce cracks, or even the smallest aperture, for absolute tightness is indispensable to success. In an apparatus of this kind, water may be combined with four or five times its bulk of carbonic acid gas, and it then dissolves iron with considerable rapidity, and the carbonates of lime and magnesia are also taken up by the excess of carbonic acid.

The containing vessel may be made of copper, tinned on the inside, and secured by being enclosed in a strong iron bound cask. This structure has the advantage of greater strength and tightness, and of being repaired with less difficulty than vessels made of wood. The only objection against it arises from the great tendency which copper has to become corroded by most chemical agents; the tin is a partial protection, but there is reason to fear that in the course of some time, the tin will become so thin as not to protect the copper, and thus a deleterious impregnation may get into the water.

2. COLD. With a given pressure more gas will be combined with water the colder it is kept during the operation. Therefore, the containing vessels should, if possible, be surrounded with ice during the impregnation, or immersed in cold water. If the vessels have been suffered to lie in an ice house and thus to become ice cold, it will greatly facilitate the combination.

3. AGITATION. Most of the remarks under this head have been already anticipated. Agitation is necessary in order to bring the water and gas into complete mixture, and to mingle water that is more highly saturated with that which is less so, that thus there may be an equal distribution of principles, which, without agitation, it would take much longer to effect. At the end of the operation the water in the containing vessel exists under a prodigious pressure. In order to create fountains of mineral waters, nothing more is necessary than to connect a proper tube with the containing vessel, and let it pass into an upper room and terminate in any convenient or ornamental jet, furnished with a stop-cock. This apparatus should be made of materials that will not contaminate the water. On opening the stop-cocks, the water will, of course, be discharged with a velocity proportioned directly to the pressure in the containing vessel, and inversely to the distance which the water has to ascend. By means of a peculiar contrivance

the impregnated water can be transferred from the containing vessel into bottles, still retaining nearly all the pressure which it had in the vessel; consequently, when the bottles are opened, the fluid will fly or sparkle as the fermented liquors do. Glass bottles are not strong enough for this purpose, and the stone ware bottles of this country are not sufficiently firm in their texture to contain the impregnated water; the pressure forces it through the sides of the bottle upon which it appears like a dew. The bottles made for this purpose in London are entirely impervious.

IV. HEPATIC WATERS.

Waters of this description are so extremely offensive, on account of the fetid odour which attends them, that they are rarely demanded as an article of manufacture. On account of the action which they exert on most metallic substances it is proper that only clean glass vessels should be used in manufacturing them; a tub of wood *not painted*, may be used as a pneumatic cistern. In impregnating water with sulphuretted hydrogen it is not necessary to employ the powerful condensing machines which have been mentioned. Were there no objection to the use of metallic instruments, still it would be unnecessary to condense into water a very large quantity of a kind of gas, of which the smallest portions can hardly be borne. Water impregnated with sulphuretted hydrogen as highly as soda water is with carbonic acid, would, when drawn, either from fountains or bottles, emit a most noxious and insupportable effluvium. To form an hepatic water, either a portion of the dry sulphurets of lime, soda, or potash, may be dissolved in water, when it will immediately acquire the hepatic odour; or (a way that is probably better) sulphuretted hydrogen gas, derived from sulphuret of iron, and diluted sulphuric or muriatic acid may be passed into an inverted bottle containing water, in the manner that was mentioned for forming the acidulous waters. Agitation being used, a sulphureous water will be obtained, sufficiently strong for medical purposes. A sulphureous bath may be formed by passing a stream of sulphuretted hydrogen gas through a tub of water, taking care to agitate the water frequently. The gas that does not combine in its passage may be caught in an inverted jar, and poured from it into another, and back again, till the water is sufficiently impregnated. The hepatic waters frequently contain some of the ingredients of the preceding classes, and these may be added by very obvious means.

In manufacturing mineral waters of every description, and especially those of the three first classes, care should be taken to select a natural water, which is, in a common sense, pure, that is, free from any peculiarity of odour, taste, or colour.

Note 40, page 272. Test for Arsenic.

Dr. Marcet, one of the physicians to Guy's hospital, London, has invented a new test for arsenic. His directions are as follows: "To the suspected fluid, previously filtered, add, first, a little dilute nitric acid, and, afterwards, nitrate of silver, till it shall cease to produce any precipitate. The muriatic acid (if any be present) being thus removed, whilst the arsenous acid (if any and in whatever state) remains in the fluid, the addition of

ammonia will instantly produce the yellow precipitate in its characteristic form. It is hardly necessary to add, that the quantity of ammonia must be sufficient to saturate any excess of nitric acid which the solution may contain. (Phil. Mag. Vol. XLI. page 124.)

The yellow precipitate here mentioned, is a compound of white oxide of arsenic, or arsenous acid with oxide of silver; the use of the ammonia is to form an arsenite of ammonia, which, by double decomposition with nitrate of silver, affords arsenite of silver, and nitrate of ammonia, which last remains in solution, while the arsenite of silver is precipitated. The nitric acid is added, to prevent the arsenite of silver, which is soluble in nitric acid, from being precipitated in mixture with muriate of silver, when muriatic acid is present; if this latter acid is not present, there is no occasion to add nitric acid. "The addition of ammonia is necessary because arsenic acid alone cannot decompose nitrate of silver; but in Fowler's solution, in which the arsenic is already combined with an alkali, the decomposition takes place at once without any addition of ammonia. The fixed alkalis can therefore answer a similar purpose; but ammonia has this advantage, that it does not, when added singly, decompose nitrate of silver, a circumstance, which, in using the fixed alkalis, might occasion some confusion." "The quantity of ammonia must not be too large, for in that case the precipitate is re-dissolved. But, even then, it may be made to re-appear by the addition of nitric acid in sufficient quantity to saturate the alkali. In this case however the precipitate is not permanent, owing to its being soluble in the nitrate of ammonia, which is formed in the process. Carbonate of ammonia has also the power of producing and re-dissolving the precipitate.

"The fixed alkalis in excess, have not the power of re-dissolving the precipitate."

APPENDIX TO THE NOTES.

Iode or Violaceous Gas.

I subjoin an account of this new substance from professor Cooper's Emporium, No. 5, page 175, having seen nothing more extensive on the subject.

IODE or VIOLACEOUS GAS. The Royal Society met, after the holidays, when a paper from Sir H. Davy was read, describing a new and important discovery. About two years ago, a Parisian manufacturer of salt petre, using all kinds of sea weed as a substitute for barilla, discovered that his vessels were excessively corroded by a particular substance of a beautiful violet colour; he communicated the fact to some Paris chemists, but no particular notice was taken of it, until Sir H. Davy went to Paris.

This new substance is easily procured, by pouring sulphuric acid on the residuum of sea weed, after the carbonate of soda has been extracted. It appears that all the vegetable products of the sea shore yield it when thus treated. By pouring the acid on the residuary ashes of the sea weed, this new and most beautiful violet coloured gas is obtained.

The French propose calling it iode gas (from the Greek word *ion, violet*) but Sir H. Davy prefers the term *violaceous* gas, as most suitable to English phraseology; its combination with hydrogen he agrees may be called *hydro-iodic-gas*, &c. Its properties are equally important to the scientific chemist and manufacturer, as a dye and pigment. It is the heaviest known gas; 100 cubic inches of it weigh 95—5 grains; it is easily disengaged at the temperature of 156°; at a low one, it condenses into fine violet coloured crystals; it is rapidly absorbed by the metals, uniting with iron, mercur

ry, tin, lead and zinc, and changing them into salts of the most beautiful tints of yellow, orange, and brown. It has many analogies with oxygen, the alkalis, and chlorine or oxymuriatic acid. Like the alkalis, it has great affinity to oxygen, from which it can be expelled by heat; it experiences no change by the action of the voltaic pile, yet rapidly combines with phosphorus, hydrogen, and all the muriates; it is a non-conductor, is very slightly combustible, yet it is a supporter of combustion. It is so easily united with all the common metals, and converts them into such fine pigments, that, before as many months elapse in this country (England) after its discovery, as years have done in Paris, it will be prepared by all our colour manufacturers, and used by our cabinet makers, wood stainers, and dyers. The existence of this substance tends to support an opinion of Sir H. Davy, that acids and alkalis do not depend on any peculiar acidifying principle, but on certain modifications of matter. All the iodats of iron and zinc are soluble in ether and spirits of wine, and many of them in water.

New Explosive Compound.

It is some time since we were informed in this country, that a new explosive compound had been discovered at Cambridge in England, by Mr. Burton; that it was formed by the action of nitrate of ammonia in solution, upon oxy-muriatic acid gas, and that it was supposed to be a compound of nitrogen and oxymuriatic acid; its explosive powers were said to be of the most terrible kind, and the chemical world heard, with much concern, that Sir Humphrey Davy had sustained a severe injury from it, which had endangered his sight. More recently, a very able and interesting report concerning this new substance has appeared in Nicholson's Journal, (Vol. xxxiv. page 180 and 276) and we are indebted to its authors, Messrs. R. Porrett, Jr. W. Wilson, and Rupert Shirk, for much curious information, some of the most important particulars of which will be mentioned in the following note.

The compound was formed by these gentlemen by filling, over warm water, glass receivers of the capacity of about sixteen cubic inches, and transferring them into small basins containing the ammoniacal saline solutions. The compound can be formed, not only from the nitrate of ammonia, but from the phosphate, muriate, sulphate and oxalate, and from the muriate of zinc with excess of ammonia, and from the muriate of ammonia and iron by sublimation. The carbonate of ammonia, triple muriate of platina and ammonia, and the sulphate of copper with excess of ammonia did not afford it. Its formation was prevented by sulphur in solution in the ammonia, or in powder within the receiver; by charcoal in fine powder, adhering to the interior moist surface of the receiver, by carbonic acid gas, or atmospherical air equal in volume to one third the chlorine gas, or by an equal volume of hydrogen gas.

It has been asserted that the compound was best formed at a temperature below freezing, but this proves to be erroneous; on the contrary, it succeeds best, if the solutions be warm; when at 90°, it was abundantly and quickly formed, and more rapidly still, when the solution was at 180°.

"As soon as the receiver of chlorine gas is placed in the solution of the ammoniacal salt, an absorption of the gas commences, and the solution rises slowly in the receiver. An action is apparent on the surface of the solution, which resembles small filaments reaching to the depth of about one tenth of an inch. These filaments, on close inspection, appear to be composed of extremely minute bubbles of gas, ranged in a line one above another to the surface. When about one fourth of the gas has disappeared, some of the explosive compound may generally be observed on the surface of the solution in a thin film; the surface then looks oily, and appears divided so as to give the idea of a map. As the solution rises in the receiver, the quantity of the explosive compound increases; and it then collects into one or two flattened globules, which, when they become very bulky, fall through the solution to the bottom. The whole of the gas is absorbed. The solution, after the formation of the compound, contains free muriatic acid, and also

some of the compound in solution, if we may judge from its smell and yellow colour." The authors of the memoir before us reason upon the hypothesis of Sir Humphrey Davy respecting chlorine, and say, that the chlorine gas is in part absorbed by the solution, " and there decomposes the ammonia of the salt, by combining with its hydrogen (with which it forms muriatic acid) and sets free its azote, to combine with another part of the chlorine, with which it forms the explosive compound." Upon the old hypothesis we should say, that the oxygen of part of the oxymuriatic acid combines with the hydrogen of the ammonia to form water ; muriatic acid is thus set at liberty, while the remaining oxymuriatic acid combines with the nitrogen, to form the explosive compound. The two theories, therefore, agree in the material fact, that the compound is essentially formed between the oxymuriatic acid and the azote.

The same explanation applies to other ammoniacal salts ; " the nature of the incombustible acid (with the exception of the carbonic) being of no importance, the only use of the acid being to prevent, by engaging the ammonia, the rapid action which the chlorine gas would exert on that alkali in an uncombined state ; the existence of it in that state would also be incompatible with that of the explosive compound." This is true, notwithstanding that the explosive compound can be formed by confining chlorine gas over a solution of pure ammonia ; but, in this case, the explosive compound is really formed from the muriate of ammonia, which is produced between the oxymuriatic acid and the ammonia.

The result of the action of oxymuriatic acid and ammonia is different according to the proportions ; if " the quantity of ammonia present in a free state, is more than the chlorine can decompose and neutralize, the whole of the chlorine gas goes to the formation of muriate of ammonia, and no explosive compound is formed, but in its stead, azotic gas is found at the termination of the experiment, equal in volume to one third of that of the chlorine gas employed"—" but when the quantity of chlorine gas present, is more than is necessary to bring the ammonia to a neutral state ; or, which is still better, when the ammonia has been previously neutralized by an acid, the azote, instead of remaining after the experiment in a state of gas, is found combined with the superabundant chlorine forming the explosive compound."

Some of the most important properties of the explosive compound are as follows : " Its colour is that of bees wax ; it is very fluid ; it sinks, although with extreme slowness, in a solution of red sulphate of iron. Hence we conclude, that it must be of the specific gravity of about 1.6. It disappears after some time, even under the surface of water, or of the solution in which it was formed ; but evaporates almost instantaneously when exposed to the air ; it then diffuses its peculiar and penetrating odour through the surrounding atmosphere, which then affects the eyes in a very painful manner, causing them to shed tears. Its action on the lungs, however, we conceive to be much milder and less prejudicial than that of chlorine gas."

The compound is difficult to keep, on account of its volatility ; if put however into a glass tube about nine inches long, of which it should fill about half an inch from the bottom, the remaining space being nearly filled with the solution ; and if the tube be then hermetically sealed by the blow pipe, it may be preserved for a length of time, but is finally dissolved in the water of the solution unless the quantity of water is small. Its volatility renders it equally difficult to transfer the compound from vessel to vessel ; this is best done by drawing it up into a small glass syringe, the piston of which may be made of wood or copper, and wrapped round with cotton ; it is easily ejected from the same instrument. It is very necessary, that every instrument employed about it should be perfectly clean, as the smallest quantity of grease, oil, or other combustible matter will cause it to explode; and, although it ordinarily does not explode without such contact, or without a temperature of 200°, yet in a course of 200 experiments three explosions took place, whose cause was completely unknown ; therefore a mask and gloves should be worn during all experiments on this substance.

This compound remained fluid at —16°; at 160° it distilled rapidly, and much gas was evolved; it did not explode at 200°, but was nearly evaporized; at 212° it exploded violently. Its exploding temperature is therefore above 200° and not above 212°.

The compound was easily converted into vapour when the pressure of the atmosphere was removed or materially diminished; by the application of red hot iron to the tube containing the vapour, it exploded, and shattered the tube.

The explosive compound was not altered by the current of galvanic electricity.

A globule of the compound was placed beneath water, in an iron ladle, or sometimes in a paper filter, and thus a great variety of substances were brought into contact with it.

Explosions more or less violent occurred with the following substances;—

Super-sulphuretted hydrogen formed by adding hydroguretted sulphuret of potash to muriatic acid.

Phosphuret of lime, phosphorus, (extremely violent,) caoutchouc, myrrh, phosphorus dissolved in liquid, sulphuretted hydrogen, phosphuretted camphor, palm oil, ambergris, whale oil, olive oil, do. camphoretted, do. sulphuretted, do. thickened by boiling on oxide of mercury, linseed oil, oil of turpentine, oil of tar, do. of amber, do. of petroleum, do. of orange peel, various metallic soaps as of silver, copper and lead, and manganese, pure fused potash (owing to the heat produced by combining with the water,) solution of pure ammonia, phosphuretted hydrogen gas, sulphuretted do. arsenic melted do. oxygen gas, nitrous gas. (A peculiar apparatus was used to bring it into contact with gases.)

Combustible bodies act on this compound with the most energy; there are however some exceptions, as in the case of ether and alcohol.

The effects appear to be owing principally to chlorine in a very condensed state, and in weak chemical union; they resemble those produced by the gas separated from oxymuriate of potash by strong sulphuric acid.

There are some combustible bodies, which unite with this compound without decomposition, of which camphor is a remarkable instance.

Animal substances appear to act with less energy than the analogous vegetable ones, of which adipocire, spermaceti, butter and lard are examples.

Earthy salts do not explode with it; among the metallic ones those formed from the nitric salts do, and those from the muriatic salts do not explode.

Our limits will not permit us to introduce the statements and reasonings of the ingenious authors of the memoir now under consideration; their general conclusions are, that the compound consists of a large quantity of chlorine gas very much condensed, and in union with a small quantity of nitrogen; they think they find reason to conclude also that hydrogen enters into the composition of the compound, and they admit that it is possible oxygen also does.

The subject is very curious, and serves to admonish us that we may be, and probably are, very far from having discovered all the active and even dangerous compounds, of which, under various modifications, matter is susceptible.

GENERAL INDEX.

[The following Index refers only to the original work, and not to the Notes of Professor *Silliman*, which are noticed only in the Table of Contents at the beginning of each vol.]

THE END.