The elements of experimental chemistry (Volume 2).

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National Library of Medicine (U.S.)

Publication/Creation

Philadelphia : Published by Robert Desilver ..., 1819.

Ex Libris, John B. Magruder

THE

ELEMENTS

OF

EXPERIMENTAL CHEMISTRY,

BY

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COMPREHENDING ALL THE RECENT DISCOVERIES.

TOGETHER WITH
An Account of Dr. Wollaston's Scale of Chemical Equivalents.
ALSO,
A Substitute for Woulfe's or Nooth's Apparatus;
AND
A New Theory of Galvanism,
BY ROBERT HARE, M.D.
Professor of Chemistry in the Med. Dep. of the University of Pennsylvania.

THE WHOLE ILLUSTRATED WITH THIRTEEN PLATES.

VOLUME II.

PHILADELPHIA:
PUBLISHED BY ROBERT DESILVER,
No. 110 Walnut-street.

1819.

ELEMENTS

OF

EXPERIMENTAL CHEMISTRY.

PART I.

CHAPTER XV.

PHOSPHORUS—PHOSPHORIC ACID—PHOSPHOROUS ACID—PHOSPHATES.

SECTION I.

Phosphorus.

I. PHOSPHORUS is an inflammable substance, and is distinguished by the following external characters.

(*a*) It has generally a flesh-red colour, but, when carefully purified, may be obtained colourless, and perfectly transparent. Its specific gravity is 1.77.

(*b*) It is so soft that it readily yields to the knife.

(*c*) It melts at about 90° Fahrenheit, and boils at 550°. When melted, it must be covered with water, in order to prevent it from inflaming.

(*d*) In the atmosphere it emits a white smoke, and a peculiar smell; and a faint and beautiful light arises from it; but these appearances do not take place in the air which has been artificially dried.

II. Phosphorus is inflamed by the application of a very gentle heat. According to Dr. Higgins, a temperature of 60° is sufficient to set it on fire, when perfectly dry. It burns when heated to about 148°, with a very brilliant light, a white smoke, and a suffocating smell, and may even be inflamed in an atmosphere rarefied sixty times.

1. It may be set on fire by friction. Rub a very small bit between two pieces of brown paper; the phosphorus will inflame, and will set the paper on fire also.

2. In oxygen gas it burns with a very beautiful light; and also in nitrous oxide, and chlorine gases.

III. Phosphorus is volatile at 550°. Hence it may be raised by distillation; but, to prevent its taking fire on the application of heat, the retort should previously be filled with azotic or hydrogen gas, and the mouth of the retort be immersed in water.

To accomplish this, the quantity of phosphorus, which it is intended to rectify, should first be put into the retort, with a sufficient portion of water to cover it. The water must then be made hot enough to melt the phosphorus, which, on cooling, forms a compact mass, of the shape of the bottom of the retort. When cold, fill the retort, and its neck also, with water, and invert it in water. Displace the water by hydrogen gas, forced from a bladder through a bent pipe; keep the finger on the open end of the retort neck; place it in a sand bath; and immerse the mouth of it in water. Then apply heat very cautiously. A bladder should also be provided, furnished with a stop-cock and brass pipe, and filled with hydrogen gas. During the distillation, the gas, in the retort, is absorbed, and it is necessary to add more from the bladder, otherwise the water will rush into the retort, and occasion an explosion. By distillation, in this mode, phosphorus is rendered much purer. In the neck of the retort a substance is condensed of a beautiful red or carmine colour, which is a combination of carbon and phosphorus, or a *phosphuret of carbon.* Thenard observes that phosphorus, however frequently distilled, cannot be freed entirely from charcoal, a minute quantity of which does not impair its whiteness or transparency.

The only information, which we possess, respecting the nature of phosphorus, is derived from the electro-chemical researches of Sir H. Davy. When acted upon by a battery of 500 pairs of plates in the same manner as sulphur, gas was produced in considerable quantities, and the phosphorus became of a deep red-brown colour. The gas proved to be phosphuretted hydrogen, and was equal in bulk to about four times the phosphorus employed. Hence hydrogen may possibly be one of its components; but no confirmation of the truth of this view is derived from the recent experiments of the same philosopher, which, indeed, are rather contradictory to it.

IV. Phosphorus may be oxygenized in various modes.*

(*a*) By exposure to atmospheric air. Let a stick of phosphorus be placed in a funnel, the pipe of which terminates in an empty bottle. The phosphorus will be slowly oxygenized, and, after some time, will be changed into an acid, which will fall into the bottle in a liquid state.

A large quantity of acid may be obtained, if a number of sticks be thus exposed: and as they would be in danger of taking fire, if heaped together, each stick should be enclosed in a glass tube, of rather larger diameter than itself. These tubes must be disposed round a funnel, the pipe of which terminates in a bottle. The whole should be covered by a bell-shaped receiver, the air of which is to

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* On the oxides of phosphorus, see Nicholson's Journal, vi. 134. Their existence is so doubtful that I have omitted them entirely.

be frequently changed. The acid thus obtained is a mixture of *phosphorous* and *phosphoric* acids, &c. Dulong, indeed, believes it to be a distinct compound, for which he has proposed the name of *phosphatic acid.*[*] But this view of its composition is not supported by the recent investigations of Sir H. Davy, who still considers it as a mixture of the two well-known acids of phosphorus.

When phosphorus is burnt in highly rarefied air, three products are formed—a red solid comparatively fixed, and requiring a heat above 212° for its fusion—a white and easily volatile substance, which is combustible, soluble in water, and has acid properties—and a substance, which is strongly acid and not volatile, even at a white heat. The first appears to be a mixture of unburned phosphorus and phosphorous acid; the second to be phosphorous acid; and the third to be phosphoric acid.

(*b*) Phosphorus inflames vividly in oxygen gas. When burnt in this manner, every hundred parts of phosphorus, according to Lavoisier, gain an addition of 154. This result scarcely differs from the original one of Sir H. Davy, who has stated that 100 grains of phosphorus condense 450 cubic inches or 153 grains of oxygen gas; but having lately examined the subject anew, with every attention to the accuracy of his results, and with the advantage of improved methods of operating, he finds that taking an average of three experiments, 100 grains of phosphorus condense 135 grains of oxygen. In this estimate, 100 cubic inches of oxygen gas are assumed to weigh 33.9 grains, the barometer being at 26.8 inches, and Fahrenheit's thermometer at from 46° to 49°.

(*c*) By the nitric acid. If phosphorus be cautiously added, by a little at once, to nitric acid, heated in a retort, the nitric acid is decomposed, and its oxygen, uniting with the phosphorus, constitutes phosphoric acid. A tubulated retort must be used for this purpose; and its neck may terminate in the apparatus already described for procuring nitric acid. By this contrivance a considerable quantity of nitric acid will be saved. The liquid, remaining in the retort, may be heated in an open capsule to a thick consistence, in order to expel the redundant nitric acid.

SECTION II.

Phosphoric Acid.

1. To prepare this acid, the process *b* or *c*, sect. i. may be employed; but the following is the most economical method.

On 20 pounds of bone, calcined to whiteness and finely powdered, pour 20 quarts of boiling water, and add eight pounds of sulphuric acid, diluted with an equal weight of water. Let these materials be well stirred together, and be kept in mixture about 24

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[*] Phil. Mag. xlviii. 273.

hours. Let the whole mass be next put into a conical bag of sufficiently porous and strong linen, in order to separate the clear liquor, and let it be washed with water, till the water ceases to have much acidity to the taste. Evaporate the strained liquor in earthen vessels, placed in a sand-heat, and, when reduced to about half its bulk, let it cool. A white sediment will form in considerable quantity, which must be allowed to subside; the clear solution must be decanted, and boiled to dryness in a glass vessel. A white mass will remain, which is the dry phosphoric acid. This may be fused in a crucible, and poured out in a clean copper dish. A transparent glass is obtained, which is the phosphoric acid in a glacial state; not, however, perfectly pure, but containing sulphate and phosphate of lime.—According to Fourcroy and Vauquelin, it is, in fact, a super-phosphate of lime, containing, in 100 parts, only 30 of uncombined phosphoric acid, and 70 of neutral phosphate of lime. The glacial acid, however, may be prepared from perfectly pure phosphoric acid, which has been made by acting on phosphorus with nitric acid. It is remarkable that, according to the experiments of Berthier, it contains at least one-fourth its weight of water, a proportion which could scarcely be expected in so hard a substance.

To procure the phosphoric acid in quantity, and at the same time perfectly pure, the oxygenation of phosphorus by nitric acid is the most eligible process (*c*, of the preceding article). The acid may be evaporated to dryness in a glass capsule; and the dry mass, when fused, affords *glacial phosphoric acid.*

II. The phosphoric acid has the following properties:

(*a*) When pure it dissolves readily in water. That obtained immediately from bones is rendered insoluble by the admixture of earthy salts. But the glacial acid prepared with nitric acid is readily soluble.

(*b*) It is not volatile, nor capable of being decomposed by heat only, nor does it emit any smell when heated.

(*c*) It is composed, according to the experiments of Rose on the combustion of phosphorus in oxygen gas, (the correctness of which is admitted by Dr. Wollaston, in his table of equivalents,) of

Phosphorus	46.72	100.
Oxygen	63.28	114.6
	100.	

Dulong investigated the composition of phosphoric acid, by finding how much chlorine is absorbed by phosphorus previously combined with a base. He then deduced the oxygen, from the quantity known to be the equivalent of the chlorine, which had disappeared. In this way, he intimates the composition of phosphoric to be

Phosphorus	44.48	100.
Oxygen	55.52	124.8
	100.	

Berzelius, by a still more complicated process, obtained results, the average of which gives 100 phosphorus to 127.5 oxygen.*

But if 235 parts of phosphoric acid, as appears from the recent experiments of Sir H. Davy, consist of 100 phosphorus, and 135 oxygen, 100 grains must contain

Phosphorus	42.55
Oxygen	57.45
	100.

This would very nearly agree with the notion, that phosphoric acid is constituted of one atom of phosphorus, weighing 11.1, and two atoms of oxygen = 15, and the weight of the atom of phosphoric acid will, therefore, be 26.1, or in round numbers 26.

(*d*) When distilled in an earthern retort with powdered charcoal, phosphoric acid is decomposed; its oxygen, uniting with the carbon, forms carbonic acid, and the phosphorus rises in a separate state. This is the usual and best mode of obtaining phosphorus.

The phosphoric acid of bones may either be employed for this purpose in the state of glass, finely powdered, and mixed with its weight of pulverized charcoal; or to the evaporated acid, when acquiring a thick consistence, powdered charcoal may be added, in sufficient quantity, to give it solidity. In the latter mode, however, the materials are apt to swell, and to boil over. The mixture of acid and charcoal is to be put in a stone-ware retort, coated with Willis's lute, the neck of which is lengthened out by a tin pipe. The open end of the pipe is to be immersed in a vessel of water. The heat is to be slowly raised, and at length made very intense. An enormous quantity of gas escapes, which takes fire on coming into contact with the atmosphere; and the phosphorus distils over in drops, which congeal in the water. As it is apt also to condense in, and to stop up, the neck of the retort and tin pipe, it must be occasionally melted out of these, by a shovel full of hot cinders, held under them. The process is rather a difficult one; and though it is proper that the student should perform it, in order to complete a course of experiments, it will be found more economical to purchase the phosphorus which may be required for experiments.

Phosphorus may also be procured, by adding to urine a solution of lead in nitric acid, which precipitates a phosphate of lead This, when well washed, dried, and distilled in a stone-ware retort, yields phosphorus† or a solution of phosphate of soda (which may be bought at the druggists), mixed with one of acetite of lead, in the proportion of one part of the former salt to 1¼ of the latter, yields a precipitate of phosphate of lead, from which phosphorus may be procured by distillation with charcoal, but at considerably more expense.

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* Ann. de Chim. et Phys. ii. 222.

† See Crell's Journal, Translation, iii. 35.

SECTION III.

Phosphates.

With alkaline and earthy bases, the phosphoric acid composes a class of salts called Phosphates, which have the following generic characters.

1. When heated with charcoal, they are not decomposed, nor is phosphorus obtained.

2. They melt, before the blow-pipe, into a hard globule, sometimes transparent, at others opaque.

3. The earthy phosphates are soluble in nitric, muriatic, and acetic acids, without effervescence, and are precipitated from those acids by lime-water and by pure ammonia.

4. They are decomposed, in part, by sulphuric acid, and yield a liquor which, on evaporation and distillation with charcoal, affords phosphorus.

The most important combinations of phosphoric acid are those which it forms with soda, ammonia, barytes, and lime.

1. *Phosphate of Soda,* obtained by saturating carbonate of soda with phosphoric acid, and evaporating the solution, exists in crystals, which have always an excess of alkali. These crystals contain 62 per cent. of water, and when calcined by a red heat are converted into a white powder, which consists of

Phosphoric acid	53.48	100
Soda	46.52	87
	100.	

Hence the crystals are composed of

Phosphoric acid	20.33
Soda	17.67
Water	62.
	100.

2. *Phosphate of Ammonia* exists with at least three different proportions of its elements. The neutral phosphate forms regular crystals, which are very soluble. By adding to this either an excess of acid or of base, we obtain distinct salts, which require farther investigation.

3. *Phosphate of Barytes* varies, also, in the proportion of its elements.

(*a*) The *neutral phosphate* may be obtained by mixing the solutions of muriate of barytes and phosphate of soda. It consists of

Phosphoric acid	31.8	100.00
Barytes	68.2	214.46
	100.	

(*b*) When the neutral phosphate is dissolved in an excess of phosphoric acid, and the solution slowly evaporated, acid crystals are obtained, which, independently of water, contain

Phosphoric acid	47.8	100.00
Barytes	52.2	107.11
	100.	

The *acid*, or *bi-phosphate*, therefore, contains just half as much barytes as the neutral compound.

(*c*) From the solution of the acid salt, alcohol occasions a bulky precipitate, which, when dried, becomes a light and white powder. It is composed of

Phosphoric acid	39.13	100.0
Barytes	60.87	155.5
	100.	

Berzelius proposes to call it the *acidulous phosphate of barytes*. In this compound the base is united with one and a half as much acid, as exists in the neutral phosphate. Water decomposes it, and changes it into the neutral variety.

4. *Phosphate of Lime*. (*a*) When a neutral solution of muriate of lime is mixed with a solution of phosphate of soda, the liquor becomes acid, and a copious precipitate takes place of small opaque fibrous crystals, which when gently dried contain

Phosphoric acid	41.90
Lime	35.42
Water	22.68
	100.

Hence the phosphoric acid and lime are to each other in the following proportions:

Phosphoric acid	54.19	100.00
Lime	45.81	84.53
	100.	

This compound may be considered as the *neutral phosphate of lime*.

(*b*) If solution of muriate of lime be poured into solution of phosphate of soda, taking care to have a considerable excess of the latter salt, a gelatinous precipitate is formed, which, when dried at a moderate heat, contains only 5.7 per cent. of water; and, after this has been expelled by heat, consists of

Phosphoric acid	48.32	100
Lime	51.68	107
	100.	

Having a greater quantity of base than the former, this compound may be termed a *sub-phosphate.* It is this substance which forms the basis of animal bone.

Both the phosphates of lime, which have already been described, are soluble in an excess of phosphoric acid, and afford a transparent solution, from which pure ammonia precipitates the neutral phosphate. From this solution, Berzelius has not succeeded in obtaining solid compounds with definite proportions of base and acid. It is probable, however, that at least one such super-phosphate exists, and that the phosphates will be found, in this respect, analogous to those salts with excess of acid, which have afforded such striking illustrations of the general law of definite proportions.

SECTION IV.

Phosphorous Acid—Phosphites.

PHOSPHOROUS acid cannot, according to Sir H. Davy, be obtained pure by exposing cylinders of phosphorus to atmospheric air; for, when thus prepared, it always contains phosphoric acid. It can only be procured in a state of purity, first, by subliming phosphorus through corrosive sublimate; then mixing the product with water and heating it, till it becomes of the consistence of syrup. The liquid obtained is a compound of pure phosphorous acid and water, which becomes solid and crystalline on cooling. It is acid to the taste, reddens vegetable blues, and unites with alkalies.

The theory of this process is, that when the compound of phosphorus and chlorine, formed in the first operation, is brought into contact with water, the water is decomposed; its hydrogen uniting with chlorine composes muriatic acid; and its oxygen combining with phosphorus forms phosphorous acid. From this mixture of acids, heat expels the muriatic.

The phosphorous acid exhales a disagreeable fœtid odour; and yields, when strongly heated, penetrating white vapours. When heated in a glass ball, blown at the end of a small tube, a gas issues from the orifice of the tube, which inflames on coming in contact with the atmosphere. Hence it appears to contain an excess of phosphorus. The residuum in the ball is phosphoric acid. From the experiments of Rose on the phosphoric acid, Gay Lussac infers that, conformably to his own hypothetical views, phosphorous acid must consist of

Phosphorus	56.81	100	132
Oxygen	43.19	76	100
	100.		

These proportions do not differ materially from those stated by Dulong, who makes phosphorous acid to consist of 100 phosphorus + 74.88 oxygen.* They agree, also, still more nearly, with the following statement of Berzelius, according to whom this acid consists of

Phosphorus	56.524	100.00
Oxygen	43.476	76.92
	100.†	

Sir H. Davy, however, after a careful investigation of the constitution of phosphorous acid, has lately been led to conclude that the oxygen, which it contains, is just one half of that existing in phosphoric acid; or that, in the former, 100 grains of phosphorus are united with 67.5 of oxygen. Hence 100 grains of phosphorous acid must consist of

Phosphorus	59.1
Oxygen	40.9
	100.

And phosphorous acid must be constituted of 1 atom of oxygen, 7.5 + 1 atom of phosphorus 11; and the weight of its atom will be 18.5.

The combinations of phosphorous acid with alkaline and earthy bases are called *phosphites*.

The phosphites differ considerably in their characters from phosphates.

1. They exhale a smell of phosphorus.
2. When heated, they emit a phosphorescent flame.
3. Distilled in a strong heat, they yield a little phosphorus, and are converted into phosphates, in which the elements are completely neutral.‡
4. They detonate, when heated with chlorate of potash.
5. They are changed into phosphates by nitric, and by oxymuriatic acid.

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* Phil. Mag. xlviii. 273.

† Ann. de Chim. et Phys. ii. 227.

‡ Gay Lussac, Ann. de Chim. et Phys. i. 212.

6. Phosphite of potash is very deliquescent, uncrystallizable, but insoluble in alcohol. Those of soda and ammonia are also very soluble. The former crystallizes in rhomboids approaching to cubes. All the rest are sparingly soluble, but can be obtained in crystals only by spontaneous evaporation, for they are decomposed by heat, and salts with excess of base are precipitated, which are absolutely insoluble. There exist, therefore, neutral phosphites, sub-phosphites, and super-phosphites, the exact composition of which remains to be investigated.[*]

SECTION V.

Hypo-phosphorous or Per-phosphorous Acid.

When phosphuret of barytes, carefully prepared, is made to act on water, two distinct compounds are generated, *viz.* phosphate of barytes, which, being insoluble, is readily separated by filtration; and a soluble salt of barytes, which passes through the filter. To the latter compound, sulphuric acid is to be added, in quantity just sufficient to separate the barytes. The acid solution which remains, when concentrated by evaporation, yields a viscous fluid, strongly acid and uncrystallizable. By a still stronger heat, this substance is decomposed; phosphuretted hydrogen is developed; a little phosphorus is sublimed; and phosphoric acid remains in the retort.[†]

The compounds of this new acid, with alkaline and earthy bases, are remarkable for their extreme solubility. Those of barytes and strontites crystallize with great difficulty. The *hypo-phosphites* of potash, soda, and ammonia, are soluble, in all proportions, in highly rectified alcohol. That of potash is even more deliquescent than muriate of lime. They absorb oxygen slowly from the air, and when heated in a retort give the same products as the acid itself.

In order to ascertain the proportions of the elements of this acid, Dulong, its discoverer, converted a known quantity of it into phosphoric acid by means of chlorine, whence he infers it to consist of

Phosphorus	72.75	100
Oxygen	27.25	37.44
	100.	

These results are calculated on the supposition that hypo-phosphorous or per-phosphorous acid is a binary compound of oxygen and phosphorus; but it is doubtful whether it may not be a triple compound of oxygen, phosphorus, and hydrogen, or a *hydracid;* in which case its proper appellation would be *hydro-phosphorous acid.*

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[*] Dulong, 48 Phil. Mag. 272.

[†] Dulong, 48 Phil. Mag. 271.

In his able investigation of the compounds of phosphorus, Sir H. Davy admits the existence of the new acid of Dulong, but deduces different proportions of its elements. The oxygen of this acid he infers to be precisely half of that which exists in phosphorous acid; or that 100 of phosphorus are united with 33.825 oxygen. But it has been already shown to be probable that phosphorous acid is composed of an atom of each of its elements; and it may, therefore, be inferred that hypo-phosphorous acid is constituted of one atom of oxygen weighing 7.5 and two atoms of phosphorus weighing 11 × 2 = 22, and the weight of the compound atom may be represented by 29.5.

The following table represents the composition of the three acids of phosphorus:

	Atoms of Phosph.		Atoms of Oxyg.		Weight of atoms.
Hypo-phosphorous acid	2	+	1	..	29.5
Phosphorous acid . .	1	+	1	..	18.5
Phosphoric acid . . .	1	+	2	..	26.

SECTION VI.

Combinations of Phosphorus with Chlorine.

There are two compounds of chlorine and phosphorus.

1. *Bi-chloride or Perchloride.* When phosphorus is introduced into chlorine gas, it takes fire spontaneously, and burns with a pale flame; and a white solid condenses on the sides of the vessel. In an experiment of Sir H. Davy, conducted with great care, 4 grains of phosphorus condensed 31.9 cubic inches (barometer 30.1, thermometer 46°) of chlorine gas, equivalent to very nearly 24½ grains, or six times its weight. Therefore 100 grains of phosphorus, to form this compound, condense 600 grains of chlorine; and as 33.5 of chlorine appear, from a variety of facts, to be equivalent to 7.5 of oxygen, the above 600 grains are, by the rule of proportion, the equivalent of 135 of oxygen; and thus is derived a collateral proof that phosphoric acid is constituted of 100 phosphorus + 135 oxygen by weight.

The solid compound of phosphorus and chlorine is volatile at a temperature below 212° Fahrenheit. It acts violently on water, the hydrogen of which forms, with the chlorine, muriatic acid; while the oxygen forms, with the phosphorus, phosphoric acid.

2. *Chloride* or *Proto-chloride.* Though this compound may be obtained by heating the perchloride with a due proportion of phosphorus, yet a better method of preparing it is (as Sir H. Davy recommends) to pass the vapour of phosphorus over corrosive sublimate, heated in a glass tube. By this process, we obtain a liquid of the specific gravity 1.45, which does not redden litmus paper, though its fumes produce this effect, in consequence of being ren-

dered acid by contact with the moisture of the air. The acid, which results from its action on water, is the phosphorous, which is best procured by the intervention of this chloride. At the same time muriatic acid is formed, by the union of chlorine with the hydrogen of the water.

In this chloride, the chlorine exists in half the quantity which constitutes the perchloride, that is, 100 grains of phosphorus are united with 300 of chlorine. But in phosphorous acid, 100 grains of phosphorus are combined with 67.5 of oxygen, which last number is, therefore, the equivalent of 300 chlorine. Now as 67.5 to 300, so is 7.5 to 33.5; indicating that in the *chloride* of phosphorus its elements are united atom to atom; while in the *per-chloride* two atoms of chlorine are combined with one of phosphorus.

	Atoms of Phosph.		Atoms of Chlor.		Weight of Atoms.
Chloride of phosphorus	1	+	1	..	41
Perchloride	1	+	2	..	74.5

SECTION VII.

Compounds of Phosphorus, with Alkalies, Earths, and Combustible Bodies.

I. Phosphorus is susceptible of combination with sulphur, and affords a compound, the properties of which vary, according to the proportion of its ingredients. It may be obtained by melting these substances together in a tube, the mouth of which is loosely stopped by paper; or by fusing these two bodies, very cautiously, and in small quantities, at the bottom of a Florence oil flask, nearly filled with water. The process is attended with some danger; and requires several precautions, which will be suggested by the essays of Mr. Accum and Dr. Briggs, published in the 6th and 7th volumes of Nicholson's Journal. The compound is much more fusible and combustible, than the separate components. It may be purified by being shaken with a solution of ammonia, and left some hours in it. Its reddish or brown colour is thus removed, and a light yellow compound results, which is semi-transparent, remains fluid even at 20° Fahrenheit, and does not act at all on water at common temperatures, nor rapidly even on boiling water. It appears to be constituted of 5 sulphur, and 7 phosphorus.*

II. Phosphorus combines with the pure fixed alkalies, and with earths, and composes the class of phosphurets. That of lime is the most readily formed, and exhibits, extremely well, the properties of these compounds. It is prepared as follows:

Take a glass tube, about 12 inches long, and one-third of an inch diameter, sealed hermetically at one end. Let this tube be coated

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* Faraday in Journ. of Science, iv. 360.

with clay, except within about half an inch of the sealed end. Put first into it a drachm or two of phosphorus, cut into small pieces, and then fill the tube with small bits of fresh burnt lime, of the size of split peas. Stop the mouth of the tube loosely with a little paper, in order to prevent the free access of air.—Next, heat to redness that part of the tube which is coated with clay, by means of a chafingdish of red-hot charcoal; and, when the lime may be supposed to be ignited, apply heat to the part containing the phosphorus, so as to sublime it, and to bring the vapour of it into contact with the heated lime. The lime and phosphorus will unite, and will afford a compound of a reddish-brown colour.—Phosphuret of barytes and of strontites may be prepared in a similar manner.

If the carbonate of lime be substituted for pure lime, the carbonic acid is decomposed. Its carbon is set at liberty, and appears in the state of charcoal; while its oxygen unites with the phosphorus; and the phosphoric acid, thus produced, forms phosphate of lime. In this process, discovered by the late Mr. Tennant, carbonic acid is decomposed by the conspiring affinities of phosphorus for oxygen, and of lime for phosphoric acid, though the former affinity only would be inadequate to produce the effect.

The phosphuret of lime has the remarkable property of decomposing water at the common temperature of the atmosphere; and the water afterwards contains phosphite, or hypo-phosphite, not phosphate, of lime.* Drop a small piece of it into a wine-glass of water, and in a short time bubbles of phosphuretted hydrogen gas will be produced; which, rising to the surface, will take fire, and explode. If the phosphuret of lime be not perfectly fresh, it may be proper to warm the water to which it is added.

Into an ale-glass put one part of phosphuret of lime, in pieces about the size of a pea (not in powder), and add to it half a part of chlorate of potash. Fill the glass with water, and put into it a funnel, with a long pipe, or narrow glass tube, reaching to the bottom. Through this pour three or four parts of strong sulphuric acid, which will decompose the chlorate; and, the phosphuret also decomposing the water at the same time, flashes a fire dart from the surface of the fluid, and the bottom of the vessel is illuminated by a beautiful green light. (Davy.)

Another combination of phosphorus, the properties of which render it a fit subject of amusing experiments, is the phosphuretted hydrogen gas.

ART. 3.—*Phosphuretted Hydrogen Gas.*

By heating solid phosphorous acid out of the contact of air, a large quantity of elastic fluid is generated, which may be collected by a proper apparatus, and has singular properties.

It has a disagreeable smell, but is not so offensive as bi-phosphuretted hydrogen. It does not explode spontaneously, but detonates

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* Gay Lussac, 85 Ann. de Chim. 206, and Ann. de Chim. et Phys. vi. 328.

violently when heated with oxygen to about 300° Fahrenheit; or when a mixture of the two gases is rarefied by diminished pressure.* It explodes in chlorine with a white flame. Water absorbs about one-eighth its volume. Its specific gravity was found by Sir H. Davy to be to that of hydrogen as 12 to 1. He gave it the name of *hydro-phosphoric gas*, but he has since adopted that of phosphuretted hydrogen.

Potassium doubles its volume, and the residue is pure hydrogen. Sulphur occasions the formation of sulphuretted hydrogen, equal in volume to twice the original gas. Three parts of it in volume condense more than five of oxygen; and one in volume absorbs four of chlorine. It appears to be constituted of two atoms of hydrogen and one of phosphorus; and the hydrogen in it is condensed into half its bulk. In that case the weight of its atom will be 13.

Its formation appears to be owing to the decomposition of water, the oxygen of which, with part of the phosphorous acid, forms phosphoric acid, while the hydrogen dissolving the excess of phosphorus existing in another portion of phosphorous acid, composes the peculiar gas.

Art. 4.—*Bi-phosphuretted Hydrogen Gas.*

I. This gas may be procured, by boiling, in a retort, a little phosphorus with a solution of pure potash. The water is decomposed; its oxygen, uniting with the phosphorus, forms phosphoric acid, which combines with the alkali, while the hydrogen dissolves another portion of phosphorus, constituting bi-phosphuretted hydrogen gas.—This gas may also be obtained, by putting into five parts of water half a part of phosphorus, cut into very small pieces, with one of finely granulated zinc, and adding three parts of strong sulphuric acid. This affords an amusing experiment. The gas is disengaged in small bubbles, which cover the whole surface of the fluid, and take fire on reaching the air; these are succeeded by others, and a well of fire is produced. (Davy.)

In preparing this gas from phosphorus and solution of potash, both the body and neck of the retort should be entirely filled with the solution, which Dr. Coxe, of Philadelphia, recommends to be almost boiling hot. He employs a retort holding from half a pint to a pint; and after introducing both the phosphorus and the solution, fixes its neck on an inclined plane formed of a block of wood, the upper extremity of which is overhung by the body of the retort, while its mouth projects over the lower end, and is dipped into a small bowl filled with a hot solution of potash. The gas, extricated by the flame of a lamp, accumulates; and, forcing the alkaline solution down the neck, at length escapes, through the hot solution in the bowl, into the air, where it inflames. Should the heat slacken, and an absorption ensue, nothing passes into the retort but the hot solution of alkali from the bowl; and this, as the retort is secured from being displaced, does no harm. In this way, a torrent of gas may be kept

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* 6 Ann. de Chim. et Phys. 304.

up, as long as there remains sufficient of the solution in the retort; and all danger of breaking the retort is entirely avoided.

II. The properties of this gas are the following:

(*a*) It takes fire immediately on coming into contact with the atmosphere. This may be shown by letting it escape into the air, as it issues from the retort, when a very beautiful appearance will ensue. A circular dense white smoke rises in the form of a horizontal ring, which enlarges its diameter as it ascends, and forms a kind of corona. The gas produces also a flash of light when admitted into the best vacuum, that can be made by an air pump.

(*b*) When mixed suddenly with oxygen gas it detonates. One measure requires 1½ of oxygen for saturation; and the product is phosphoric acid. It may also be combined with an equal volume of oxygen, and the product is then phosphorous acid.

This experiment should be made cautiously, and in small quantity. But in a tube only three-tenths of an inch in diameter, the mixture does not detonate.

(*c*) The same phenomenon ensues on mixing it with chlorine gas, or with nitrous oxide. Three volumes of chlorine are condensed by one of phosphuretted hydrogen; and the products are muriatic acid and perchloride of phosphorus.

When mingled with any of these gases, it should be passed up by not more than a bubble or two at once.

(*d*) Sulphurous acid and phosphuretted hydrogen gases, when mingled together, mutually decompose each other.

(*e*) It deposits phosphorus, by standing, on the inner surface of the receiver, and loses its property of spontaneous ascension. It is, also, decomposed by electricity, without any change of volume.

(*f*) Its specific gravity is very variable. Sir H. Davy has obtained it, from phosphorus and alkaline lixivia, of all specific gravities, from 400 to 700; Mr. Dalton states it at 850, air being 1000, and Dr. Thomson at 902.2. The quantity absorbed by water is stated by the former at one-fortieth its bulk, and by the latter at one-twenty-seventh. Dr. Thomson makes it one-fiftieth.

(*g*) Two measures of the gas heated with potassium become three, and phosphuret of potassium is formed.

From all that is known respecting this variety of phosphuretted hydrogen it may be inferred to consist of 1 atom of hydrogen + 1 atom of phosphorus; and the weight of its atom will be represented by 12.0.

The existence of different varieties of phosphuretted hydrogen has, however, been lately denied by Mr. Dalton, whose experiments have led him to the conclusion, that the apparent diversities of composition are occasioned by the admixture of various proportions of free hydrogen and phosphuretted hydrogen. The two gases admit, he finds, of separation by liquid oxymuriate of lime, which absorbs the phosphuretted hydrogen, and not simple hydrogen.

One volume of phosphuretted hydrogen in a pure state requires, according to Dalton, two volumes of oxygen for saturation. When electrified *per se*, it is expanded one-third of its volume. It is absorbed by eight times its bulk of water. When two parts are mixed with five of nitrous gas, and an electric spark is passed through the mixture, a brilliant explosion takes place; and the results are phosphoric acid and water, and nitrogen gas, less in bulk by 2 or 3 per cent. than half the volume of the nitrous gas.*

Phosphorus is soluble in oils; and, when thus dissolved, forms what has been called liquid phosphorus, which may be rubbed on the face and hands without injury. It dissolves too in ether, and a very beautiful experiment consists in pouring this phosphoric ether in small portions, and in a dark place, on the surface of hot water.

The phosphoric matches consist of phosphorus extremely dry, minutely divided, and perhaps a little oxygenized.—The simplest mode of making them is to put a little phosphorus, dried by blotting-paper, into a small phial; heat the phial, and when the phosphorus is melted, turn it round, so that the phosphorus may adhere to the sides. Cork the phial closely; and it is prepared. On putting a common sulphur match into the bottle, and stirring it about, the phosphorus will adhere to the match, and will take fire when brought out into the air.

CHAPTER XVI.

BORACIC ACID.

I. THIS acid is very rarely to be found native; and, for purposes of experiment, is obtained from the purified borax of commerce, by one of the following processes:

1. To a solution of borax, in boiling water, add half its weight of sulphuric acid, previously diluted with an equal quantity of water. Evaporate the solution a little; and, on cooling, shining scaly crystals will appear, which consist of boracic acid. Let them be well washed with distilled water, and dried on filtering paper.

2. Let any quantity of borax be put into a retort, with half its weight of sulphuric acid, and half its weight of water. Boracic acid may be obtained by distillation, and may be purified, by washing in water, &c., as before. By neither of these processes, however, is it obtained perfectly pure; for electrical analysis discovers in it a minute portion both of alkali and of sulphuric acid. (Davy.)

II. Boracic acid has the following qualities:

1. It has the form of thin white scales; is destitute of smell, and nearly so of taste. Its specific gravity is 1.479.

2. It fuses, when heated, and loses its water of crystallization. If the heat be increased suddenly, before it has lost its water of crystallization, it sublimes; but, otherwise, it melts into a glass,

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* Thomson's Annals, xi. 7.

which is permanent in the strongest fire, and has the specific gravity 1.803.

3. It is generally described as soluble in twelve parts of cold water, and in three or four of boiling water; but, according to Sir H. Davy, even boiling water does not take up above one-fiftieth of its weight.

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

5. It is soluble in alcohol, and the solution burns with a beautiful green flame.

The boracic acid, which had resisted all other means of analysis, has at length yielded to the attempts of Sir H. Davy to decompose it by the action of Voltaic electricity. When slightly moistened with water, and exposed, between two surfaces of platina, to a battery of 500 pairs of plates, an olive-brown matter immediately began to form on the negative surface, which gradually increased in thickness, and at length became almost black. It was not changed by water, but dissolved with effervescence in warm nitrous acid. When heated to redness on platina, it burned slowly, and gave off white fumes, which had acid properties. A black mass remained, which, when examined by the magnifier, appeared vitreous at the surface, and evidently contained a fixed acid.

Boron.

As this peculiar combustible substance is a non-conductor of electricity, it was found impossible to obtain it in this way, except in very thin films. By the action of potassium, however, it was procured in larger quantities. Twelve or fourteen grains of boracic acid were heated, in a green glass tube, with the same quantity of potassium. A most intense ignition ensued; and the potassium, where it was in contact with the boracic acid, entered into vivid inflammation. A quantity of hydrogen gas appeared, equal to about twice the bulk of the acid. To collect the results, tubes of metal were employed; for the most part of brass, which appears to answer best. The residue in the tube was dissolved in water, and the insoluble part collected on a filter. Its properties are described as follows:

1. It is in the form of a powder, in colour of the darkest shade of olive. It is very friable, and not sufficiently hard to scratch glass. It is a non-conductor of electricity.

2. When it has been dried at only 100° or 120°, it gives off moisture by increase of temperature. In the atmosphere it takes fire, at a heat below that of boiling olive oil; and burns with a red light, and scintillations like charcoal.

3. It is not decomposed by heat in a platina tube, though raised to whiteness. The only change in it appears to be an increase of specific gravity.

4. In oxygen gas it burns with a most brilliant light, and is partly converted into boracic acid, and partly into a black substance, which requires a higher temperature for its inflammation, and produces a fresh quantity of boracic acid.

5. In oxymuriatic acid gas, it takes fire at common temperatures, and boracic acid is regenerated with a portion of the black matter already described.

6. It is not soluble either in nitrogen or hydrogen gases.

7. It decomposed the nitric and sulphuric acids, and boracic acid was produced.

8. It combined with alkalis, and gave pale olive coloured compounds, from which dark precipitates were separated by muriatic acid.

9. It slowly combined with melted sulphur, which acquired an olive tint; but with phosphorus scarcely any union seemed to take place. Neither did it combine with mercury.

These qualities are sufficient to show that the combustible substance, obtained from boracic acid, and constituting its base, is different from every other known species of matter. Sir H. Davy has, therefore, proposed for it the term BORON. As to its nature, he is of opinion that it is probably a compound, and that one of its ingredients, which enters into alloy with potassium and with iron, is the true basis of the boracic acid. The olive coloured substance, whose properties have been already described, he believes to consist of this basis, united with a little oxygen; that when further oxydized it forms the black matter; and that, in its full state of oxygenation, it constitutes boracic acid.

The proportion of ingredients in the boracic acid has not been accurately determined. It is stated, merely as an approximation, that it consists of one part by weight of inflammable base united with two parts of oxygen. In the black substance, Sir H. Davy supposes that about three parts of the inflammable base are combined with only one of oxygen.

Boracic acid combines with alkalis and earths; but the only important combination, which it forms, is with soda. This compound is found native in India, and is brought to this country, under the name of tincal, or brute borax, which, when purified, affords the borax of the shops. In the borate of soda, the alkaline ingredient is in excess, and hence the salt converts vegetable blue colours to green. It is therefore, in strictness, a sub-borate.

Sub-borate of soda crystallizes in prisms with six irregular sides. It effloresces in the air. It fuses when ignited; loses its water of crystallization; and leaves a glass, which is transparent when cold, and which is of great use in experiments with the blow-pipe. The salt dissolves in twelve parts of cold water, or in six of boiling water. It is susceptible of combination, by fusion, with silex and with alumine; and hence is employed in making artificial gems. According to the experiments of Gmelin, it consists of

Boracic acid	35.6 . . .	100
Soda	17.8 . . .	50
Water	46.6	
	100.	

The remaining borates, which have been analyzed by Gmelin, are described in the 9th volume of Dr. Thomson's Annals, p. 48.

CHAPTER XVII.

FLUORIC ACID.

I. THE fluoric acid may be obtained from a substance found abundantly in Derbyshire, under the name of *fluor spar*. In converting this spar to ornamental purposes, small pieces are broken off, which may be had at a cheap rate.

Pure fluoric acid has never yet been obtained in a gaseous state; for we are acquainted with it, as a gas, in only two forms, viz. 1stly, of combination with silex; and 2dly, with boracic acid.

Silicated fluoric gas may be prepared by pouring on fluor spar, finely powdered, and mixed with half its weight of powdered glass, an equal weight of strong sulphuric acid. It may be received over mercury in glass vessels, the transparency of which it does not impair. Its specific gravity is very great, 100 cubic inches weighing 110.78 grains.

By causing a known volume of it to be absorbed by liquid ammonia, Dr. John Davy separated the silex, which formed 61.4 per cent. of the weight of the gas. When the gas is absorbed by water, much of the silex is deposited, and it retains only 54.5 per cent. of that earth in combination. To this liquid, Dr. Davy gives the name of *subsilicated fluoric acid*.

Water absorbs about 263 times its bulk of the gas, and the solution may be kept in glass vessels without corroding them.

It condenses twice its volume, and no other proportion, of ammoniacal gas, forming a dry white salt, which is slightly acid; deposits some silex when dissolved in water; and, when its concentrated solution is boiled in glass vessels, powerfully corrodes them. When an excess of liquid ammonia is added, the whole of the silex is precipitated, and a pure fluate of ammonia is obtained.

Potassium, heated in silicated fluoric gas, takes fire, and burns with a deep red light. In an experiment of Sir H. Davy, after the combustion, the whole of the fluoric acid was found to be destroyed, and no gas left but a residuum of hydrogen. But from fluoric acid, long exposed to calcined sulphate of soda, hardly one-tenth its bulk of hydrogen could be thus developed.

The bottom of the retort, in these cases, was covered with a substance of various colours, in some parts chocolate, in others yellow, which, being heated in contact with air, burned slowly, lost its colour, and became a white saline mass. In oxygen gas, it burned with an absorption of oxygen, but not with any great intensity, reproducing silicated fluoric acid gas.

By the action of this substance on water, fluoric acid and potash were generated; and some chocolate-coloured particles were separated by the filter, which, when dried, and heated in oxygen gas, burned and absorbed oxygen. By this combustion, fluoric acid was also generated.

Hydro-fluoric Acid.

The fluoric acid may be obtained *in a liquid state,* from fluor spar and twice its weight of strong sulphuric acid, by using a leaden retort and leaden receiver. An ingenious apparatus, invented for this purpose by Mr. Knight, is described and figured in the 17th volume of the Philosophical Magazine. The receiver should be surrounded with snow or pounded ice.

The liquid acid must be preserved in leaden or silver bottles, as it soon corrodes and penetrates glass ones. Its volatility, however, is such that it is extremely difficult to confine it. In this state of watery solution, it readily combines with alkalies, and forms soluble compounds. Its combinations with the earths are for the most part highly insoluble. The fluates have no properties that can render them interesting to the student, except the use of the alkaline ones as tests, which will be described in a subsequent part of the work.

To the liquid solution of fluoric acid, Gay Lussac and Thenard have given the name of *silici-fluoric* acid. Its specific gravity, Sir H. Davy finds to be 1.0609. By adding water, in very small quantities at once, its specific gravity is gradually increased to 1.25, a property observed in no other liquid. When suddenly mixed with water, it becomes very hot and even boils; it emits dense and noxious vapours; acts instantly and strongly on glass; and powerfully affects the skin, on which it raises painful pustules, or, if in sufficient quantity, occasions deep and dangerous ulcers.—A small piece of potassium thrown into it detonates violently.

The principal use of hydro-fluoric acid is for destroying the polish of glass; but for this purpose it is adviseable to prepare it in a state of considerable dilution, by receiving the gas into water, contained in a leaden vessel. It may, also, be employed to etch on glass, as copper is engraved by aqua fortis; and it affords an useful means of separating potash from its acid combinations, since it detaches that alkali in the form of an insoluble compound.*

Nature of Fluoric Acid.

The experiments of Sir H. Davy, made in 1808, led him to conclude, chiefly from the action of potassium on silicated fluoric gas, that the fluoric acid is a compound of oxygen with a combustible basis. But as all acids, so constituted, are decomposed by galvanic electricity, their base being determined to the negative, and their oxygen to the positive pole, he has lately† submitted liquid fluoric acid to this test, after having first ascertained, by the result of its combination with ammoniacal gas, that, in its strongest form, it contains no water. Considerable difficulty was experienced in making the necessary exposure of

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* Wheeler in Journal of Science, &c. iv. 287.

† Phil. Trans, 1813, part 2; and 1814, part 1.

the liquid to electricity, (partly in consequence of the dangerous fumes which it emitted,) and also in collecting the products. At the negative pole, a gas was evolved, which, from its inflammability, appeared to be hydrogen. The platina wire at the positive pole was rapidly corroded, and covered with a chocolate powder, the properties of which seem not to have been examined.

When fluate of ammonia was treated with potassium, no evidence was obtained of its containing oxygen. Charcoal, also, intensely ignited in fluoric acid gas, gave no carbonic acid. The most simple way of explaining the phenomena appears, therefore, to Sir H. Davy, to be by the supposition, that the fluoric acid, like the muriatic, is composed of hydrogen, and a peculiar base, possessing, like oxygen and chlorine, a negative electrical energy, and hence determined to the positive surface. For this base, which, like chlorine, he believes to combine at once with metals, the name of *fluorine* has been proposed. This substance, from its strong affinities and decomposing agencies, has not yet been exhibited in a separate state; nor have any of the attempts to detach it from its combinations by chlorine or oxygen, (on the presumption that the attraction of one of those bodies for the metals might be superior to that of fluorine,) been hitherto successful.

The number representing the atom of *fluorine*, as deduced from the composition of fluor spar, is 17.1; and fluor spar must be composed of 20 calcium and 17.1 fluorine. On the whole, Sir H. Davy is disposed to estimate the weight of the atom of fluorine at less than half that of chlorine, and to fix it at 33, which is equivalent, on Mr. Dalton's scale, to 16.5

Fluoboric Acid.

With the view of obtaining fluoric acid gas perfectly free from water, both Sir H. Davy and Gay Lussac appear to have had recourse to the same expedient, *viz.* that of distilling perfectly dry boracic acid with fluate of lime. When these substances were exposed to a strong heat in an iron tube, in the proportion of one part of the former to two of powdered fluor spar, a gas was collected in great quantity, which exhibited singular properties, and to which Messrs. Gay Lussac and Thenard have given the name of *gas fluoborique*, or fluoboric acid gas. It may, also, be obtained by distilling in a retort one part of vitreous boracic acid with two of fluor spar and 12 of sulphuric acid. One hundred cubic inches weigh 73.5 grains.

This gas, according to the latter chemists, appears to contain no water, and to have so strong an affinity for it as to take it from other gases, which hold water in combination. Hence, when mixed with most of those gases, on which it does not exert a chemical action, such as atmospheric air, it loses its transparency and becomes cloudy.

With ammoniacal gas it unites in two proportions. If the alkaline gas be put first into the tube, equal measures combine together, and the compound is neutral. But if we admit fluoboric gas by bubbles to the alkaline gas, we obtain a compound, with an excess of base, consisting of one measure of fluoboric gas to two of ammonia.

Fluoboric gas is absorbed copiously by water, which takes up 700 times its bulk, and acquires the specific gravity 1.77. The saturated solution has the causticity and aspect of strong sulphuric acid; requires for ebullition a temperature considerably exceeding 212° Fahrenheit; and is condensed again in striæ which contain much gas. From analogy, Gay Lussac supposes that nitric and even sulphuric acids would, if they could be obtained free from water, be equally elastic with this.

When potassium or sodium was heated in fluoboric gas, Gay Lussac and Thenard obtained fluate of potash or soda, and the base of the boracic acid.

The liquid acid acts almost as intensely as sulphuric acid on vegetable substances. It blackens paper, and affords a true ether with alcohol. It has no effect in corroding glass.

From analysis, Gay Lussac and Thenard, as well as Sir H. Davy, have determined it to be a compound of boracic and fluoric acids, in proportions not yet ascertained.

CHAPTER XVIII.

IODINE AND ITS COMPOUNDS.

IODINE was discovered accidentally, about the beginning of the year 1812, by M. Courtois, a manufacturer of saltpetre at Paris. In the processes for procuring soda from the ashes of sea weeds, he found his metallic vessels much corroded; and in searching for the cause, he made this discovery. Specimens of the new substance were given to MM. Desormes and Clement, who read a short memoir upon it, at a meeting of the Institute of France, in November, 1813. Its properties and combinations have since been ably investigated by Vauquelin;[*] by Gay Lussac;[†] by Sir H. Davy;[‡] and by Gaultier de Claubry and Colin.[§]

When all the soda has been separated by crystallization from a solution of kelp or barilla, or from the ley of ashes of marine plants, that afford the mineral alkali, in order to procure iodine from the residuary liquor, concentrated sulphuric acid is to be poured upon it, in a retort furnished with a receiver. The iodine passes into the receiver, under the form of beautiful violet vapours, which are condensed in crystalline plates, having the aspect of plumbago. To purify it from the redundant acid, that comes over with it, the iodine may be re-

[*] 90 Ann. de Chim. 206.

[†] 91 Ann. de Chim.

[‡] Phil. Trans. 1814.

[§] 90, 91, and 93 Ann. de Chim.

distilled from water, containing a very small quantity of potash, and afterwards dried by pressing it between folds of blotting paper.*

General Properties.—Iodine is a solid, at the ordinary temperature of the atmosphere. It is often in scales, resembling those of micaceous iron ore; sometimes in large and brilliant rhomboidal plates; and occasionally in elongated octohedrons.† Its colour is bluish black; its lustre metallic; it is soft and friable, and may easily be rubbed to a fine powder. Its taste is very acrid, though it is sparingly soluble in water, which does not take up above one 7000th part of its weight. Its specific gravity, at 60° Fahrenheit, is 4.946. It is a non-conductor of electricity; and possesses, in a high degree, the electrical properties of oxygen and chlorine, being determined to the positive pole of a galvanic arrangement. When applied to the skin, it produces a yellow stain, but this disappears as the iodine evaporates.

Iodine is fusible at 225° Fahrenheit, and, under the ordinary pressure of the atmosphere, is volatilized at a temperature somewhere near 350°, forming a gas 117.71 times denser than hydrogen, or, according to Sir H. Davy, weighing 95.27 grains for 100 cubic inches. The volatilization of iodine at the heat of boiling water, which happens when it is distilled with that fluid, depends on its affinity for aqueous vapour. The colour of its vapour is a beautiful violet, and hence its name (from ιωδὴς, violaceus).

Action of Oxygen.—Iodine undergoes no change by being heated in contact with oxygen gas, or with hyperoxy-muriate of potash. It will appear, however, in the sequel, that, by the intervention of euchlorine, it admits of being combined with oxygen, and that it then furnishes a peculiar acid with that body.

Action of Nitrogen.—Azotic gas has no action on iodine, but a compound of iodine nitrogen will be described in speaking of the effect of ammonia.

Action of Water.—It has no power of decomposing water, even when the mixed vapours of the two substances are passed through a red hot tube.

Action of Hydrogen.—The affinity of iodine for hydrogen is very strong, and it absorbs that basis from hydrogen gas, and detaches it from several of its combinations, affording, as the result, a distinct and well characterized acid.

If iodine be heated in dry hydrogen gas, an expansion of its volume takes place; an acid gas is formed, which is very absorbable by water, and acts so much on mercury that it cannot be preserved long over that metal. A similar gaseous compound is formed, by exposing iodine to sulphuretted hydrogen gas. But it is best prepared, in quantity, by the action of moistened iodine and phosphorus on each other, the phosphorus being in excess, and the mixture distilled in a retort. The gas may be received into a vessel filled with common

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* More minute directions for its preparation are given in the Phil. Mag. xl. 57, 141, and 209.

† Dr. Wollaston has described the form of its crystal in Thomson's Annals, v. 237. See also Journ. of Science, &c. v. 364.

air, which it expels by its superior gravity. Gay Lussac recommends, instead of a retort, a small bent tube, which, after putting the iodine into it, is to be inverted over mercury; the air, which it contains, is to be expelled by a glass rod, that almost fills its capacity; and the phosphorus is to be brought into contact with the iodine, by introducing it through the mercury. As soon as the contact takes place, the acid gas is disengaged, and may be collected by putting the open end of the tube under a glass jar standing inverted in mercury.

No sooner does the gas come into contact with the mercury, than it begins to be decomposed; and if the contact be prolonged a sufficient time, or agitation be used, the decomposition is complete. The iodine unites with the mercury; and there remains a volume of hydrogen gas, which is exactly one half that of the acid gas. It is decomposed, in a similar manner, by all metals, except gold and platinum.

The acid gas is colourless, its taste is very sour, and its smell resembles that of muriatic acid gas. Its specific gravity was found by experiment to be 4.443; by calculation it should have been 4.428.

The acid gas is rapidly decomposed by being heated in contact with oxygen gas, which detaches the hydrogen. Chlorine also, instantly deprives it of hydrogen, and produces muriatic acid gas; and the iodine re-appears in the form of a beautiful violet vapour. When mixed with proto-phosphuretted hydrogen, both gases are condensed into white cubical crystals, which are volatilized at a moderate heat without fusion or decomposition.* It is composed, by weight, according to Gay Lussac, of 100 iodine and 0.849 hydrogen.

For this compound Sir H. Davy has proposed the name of *hydroionic acid*, and Gay Lussac that of *hydriodic acid*. I prefer the latter; because it is easier, by varying its termination, to express its combinations with alkaline and other bases.

Hydriodic Acid Gas is plentifully absorbed by water; the solution is fuming, and has the density of 1.7. To prepare this liquid in quantity, Gay Lussac rcommends to put powdered iodine into water, and to pass sulphuretted hydrogen gas through the mixture. The hydrogen unites with the iodine, and the sulphur is precipitated. The liquid may be concentrated by evaporation. Till it attains the temperature of 257°, water only distils; above this point, the acid itself is volatilized, and remains stationary at 262½°, its density being then 1.7.

The liquid acid is slowly decomposed by contact with air; its hydrogen being attracted by the oxygen of the atmosphere, and a portion of iodine liberated, which gives the liquor a colour of intensity proportionate to the quantity of free iodine. Concentrated sulphuric acid, nitric acid, and chlorine, decompose it, and separate iodine. With solutions of lead, it gives a fine orange precipitate; with solution of per-oxide of mercury, a red one; and with silver, a white precipitate, insoluble in ammonia.

When submitted to Galvanic electricity, the liquid hydriodic acid is rapidly decomposed; iodine appears at the positive, and hydrogen

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[*] 6 Ann. de Chim. et Phys. 305.

at the negative pole. It dissolves zinc and iron, with a disengagement of hydrogen gas, which proceeds from the water. It has no action on mercury, though the gas so powerfully affects that metal. It is decomposed by those oxides, which hold their oxygen loosely, and combine with the rest, forming a genus of neutral salts, called *hydriodates.*

In general, the hydriodates are readily soluble in water. Those of potash and barytes are not decomposed by heat, except oxygen is in contact with them; the salt with base of lime is wholly, and that with base of magnesia partially, decomposed at high temperatures.

Charcoal does not combine with iodine.

Sulphur and Iodine unite at a gentle heat, and a black radiated compound is formed, resembling sulphuret of antimony. It is easily decomposed by a degree of heat a little higher than that at which it was formed, and iodine is detached in vapour.

Phosphorus and Iodine combine at the temperature of the atmosphere, according to Sir H. Davy, evolving much heat, but no light; but, according to Thenard, with a disengagement both of light and heat. The result is a *phosphuret of iodine,* of a reddish brown colour, the solidity, fusibility, and volatility of which vary with the proportions of its ingredients. If both the phosphorus and iodine are dry, no gas is given out during their combination; but, when slightly moistened, hydriodic acid is formed, by the union of iodine with the hydrogen of the water; a little subphosphuretted hydrogen is produced; and phosphorous acid remains in solution. The hydriodic acid gas is also formed, when the phosphuret of iodine, produced from dry materials, is added to water.

Potassium and Iodine.—Potassium burns in the vapour of iodine with a pale blue light, and without the disengagement of any gas. The substance produced is white; fusible at a red heat; and soluble in water. It has a peculiar acrid taste. When acted upon by sulphuric acid, iodine is set at liberty. The same compound is obtained, by heating potassium in hydriodic acid gas, which is decomposed, and yields half its volume of hydrogen gas. To this compound Sir H. Davy has given the name of *iode of potassium,* the term *iode* being a generic one for the compounds of iodine with the metals and other combustible bases. Gay Lussac has proposed the name of *iodure;* but it is more conformable to analogy with the similar compounds of oxygen and chlorine to give, to the combinations of iodine with combustible bases, the appellation of *iodides.*

When *iodide* of potassium, silver, mercury, or lead, is heated in chlorine gas, iodine is expelled, and hence the affinity of chlorine for those metals surpasses that of iodine. Sulphuric acid extricates some iodine, and occasions a production of hydriodic and sulphurous acids. Oxalic, acetic, sulphurous, and phosphoric acid have no action on the iodurets.

Iodine and Alkalies.—When iodine in vapour is passed over ignited hydrate of potash, oxygen is disengaged, and a compound is formed, precisely similar to that which results from the combination of iodine and potassium. Hence the affinity of iodine for potassium exceeds that of oxygen; and the same may be said of several other metals, though not of all, their oxides being decomposed by iodine. From subcarbonate of potash, it displaces two volumes of carbonic acid and one of oxygen.

When iodine is thrown into a moderately strong solution of potash, rendered perfectly caustic, it is dissolved; and, during its solution, crystals fall down, which may be obtained abundantly, by saturating the liquid with iodine. To obtain these crystals pure, they must be washed with alcohol of a specific gravity, between .860 and .920. They are sparingly soluble in water; have a taste like hyper-oxymuriate of potash; deflagrate with charcoal; and when heated give oxygen gas, and iodide of potassium. With sulphuric acid, they afford iodine, oxygen, and sulphate of potash.

The liquid, which has ceased to yield these crystals, affords, on evaporation, a salt identical with iodide of potassium. In this case, Sir H. Davy imagines the potash is decomposed; one part of it combines with iodine, and the oxygen, thus set at liberty, unites with the other part and with iodine. In his view, therefore, the deflagrating salt is a triple compound of oxygen, iodine, and potassium, and is called an *oxyiode;* but Gay Lussac supposes that the iodine is oxygenated, and forms an acid, which he calls *iodic acid;* and that this, uniting with potash, composes *iodate of potash.* By acting with iodine on solution of barytes, a similar compound was formed with that earth, which, when decomposed by sulphuric acid, gave, he supposes, a mixture of that acid with *iodic acid.* But the product, in this case, Sir H. Davy has since shown, is a compound of sulphuric acid with oxyiodine, which will presently be described.

Dry ammoniacal gas is absorbed by iodine without decomposition; the product is at first very viscid, and has a metallic aspect; but by an excess of ammonia, it loses these properties, and becomes of a very deep brownish-red. When iodine is added to liquid ammonia, one part of it unites with the hydrogen of the alkali, and forms hydriodic acid, while another portion of iodine combines with the azote, and falls down in the form of a black powder. This compound of azote and iodine detonates with a very gentle heat, and even with the slightest touch.

Iodine and Chlorine.—Iodine absorbs less than one-third its weight of chlorine, and forms a peculiar acid which may be called *chloride,* or *chloriodic acid,* and its compounds *chloriodates.* According to Gay Lussac, indeed, two compounds result, the one of a fine orange-yellow colour, containing the largest proportion of chlorine, the other orange-red. Both are solid and crystalline; deliquiate when exposed to the air; are fusible into an orange liquid; and give an orange-coloured gas. The watery solution takes more iodine, and acquires a deep colour; but if agitated with chlorine, it is deprived of colour, and when poured in that state, into solution of potash, the deflagrating salt is precipitated. From liquid ammonia, the colourless liquid precipitates a white detonating compound; but the coloured solution throws down the darker compound, which detonates on the slightest touch, and is, indeed, identical with that procured by the direct action of iodine on ammonia.

Chloriodic acid (or *chlorure of iodine*, as it called by Gay Lussac) precipitates the salts of iron, lead, tin, and copper; probably in the state of oxyiodes.

It has been observed by Gay Lussac, that, in order to convert the whole of a quantity of alkali into the deflagrating salt, without any of the hydriodate, (which otherwise is produced in greater proportion than the oxyiode), it is necessary, first, to combine the iodine with chlorine; and, after dissolving the compound in water, to saturate it with alkali.

Iodine and Euchlorine.—When iodine is exposed to euchlorine, Sir H. Davy has discovered,* that there is an immediate action; its colour changes to bright orange; and a liquid is formed. By the application of a gentle heat, the orange compound of chlorine and iodine is expelled, and a compound of oxygen and iodine remains. This substance is a white semi-transparent solid; it has no smell, but a strong astringent sour taste. Its specific gravity is such, that it sinks in sulphuric acid.

When decomposed by heat in a pneumatic apparatus, it is resolved into oxygen gas and pure iodine; and it is, therefore, termed by Sir H. Davy, *oxyiodine;* by Gay Lussac, *acide iodique anhydre.* Thirteen grains afforded 9.25 cubical inches of oxygen gas, = 3.14 grains. Hence it is composed of

Iodine	75.85	100.	314.8
Oxygen	24.15	31.84	100.
	100.	131.84	414.8

On the supposition that *oxyiodine* is composed of five atoms of oxygen and one of iodine, the atom of iodine may be deduced to weigh 117.15, Now it is remarkable, that assuming hydriodic acid to consist of one atom of iodine and one of hydrogen, the weight of the atom of iodine is 117.77; for as .849 to 100 (the proportions in which hydrogen and iodine combine) so is 1 to 117.77. If 10 represent the atom of oxygen, then the atom of iodine will weigh 150.62.

Oxyiodine is very soluble in water, and is slightly deliquescent. Its solution, called by Gay Lussac *acide iodique*, first reddens, and then destroys, vegetable blues, and reduces other vegetable colours to a dull yellow. When evaporated sufficiently, it becomes a thick pasty substance, and at length, by a cautiously regulated heat, yields oxyiodine unaltered.

When heated in contact with inflammable bodies, or with the more combustible metals, detonations are produced. Its solution in water rapidly corrodes all the metals, and even acts on gold and platinum, but especially the first.

When its solution is poured into solutions of alkalies, or alkaline earths, or when made to act on their carbonates, triple compounds are formed of oxygen, iodine, and the metallic bases, called by Sir H.

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* Phil. Trans. 1815, part 2.

Davy, *oxyoides;* and by Gay Lussac, it would appear improperly, *iodates.* With solution of ammonia, it composes oxyiode of ammonia; and from the soluble salts of barytes and strontites, it precipitates their respective oxyiodes. Forty-eight grains of oxyiode of potassium, when decomposed by heat, afforded Sir H. Davy 31 cubic inches, = 10.5 grains of oxygen gas.

Oxyiodine enters into combination with all those fluid or solid acids, which it does not decompose. Sulphuric acid, dropped into a saturated solution of it in hot water, precipitated a solid, which, on cooling, formed rhomboidal crystals of a pale yellow colour. This compound is fusible; and, with a heat properly regulated, may be sublimed unaltered. Hydronitric and hydrophosphoric acids afford analogous compounds. Oxalic and liquid muriatic acids decompose it. All its acid combinations redden vegetable blues; dissolve gold and platinum; and when added to alkalies or earths, afford common neutral salts, and their respective oxyiodes. In their crystalline state, the compounds of oxyiodine and acids are most probably hydrates; the acids carrying with them, into combination, their definite proportion of water.

For the watery solution of oxyiodine, Sir H. Davy has proposed the name of *oxyiodic acid*, and is disposed to regard it as a triple compound of iodine, hydrogen, and oxygen; or an *oxyiode of hydrogen.*

Iodine and Metals.—All the metals, with the aid of heat, unite with iodine, and form *iodes, iodides,* or *iodurets,* analogous, according to Gay Lussac, to sulphurets. When these compounds are placed in contact with water, it is decomposed, and a hydriodate of the respective metal is produced, the water furnishing hydrogen to the iodine and oxygen to the metal.

Nature of Iodine.—Iodine, from all that we yet know respecting it, is to be considered as a simple or elementary body, having a very striking analogy with chlorine, which it resembles, 1stly, in forming one acid by uniting with hydrogen, and a different acid with oxygen; 2dly, in its effects on vegetable colours; 3dly, in its affording, with the fixed alkalies, salts which nearly approach in characters to chlorates or hyper-oxymuriates; and 4thly, in its electrical habitudes. Its discovery, indeed, lends strong support to that theory, which considers chlorine as a simple body, and muriatic acid as a compound of chlorine and hydrogen. In the property of forming an acid, whether it be united with hydrogen or with oxygen, iodine bears, also, an analogy to sulphur; and it is remarked by Gay Lussac of the combinations of chlorine, iodine, and sulphur, with the elements of water, that while the acids, which they respectively form with oxygen, have their elements strongly condensed, those formed with hydrogen have their elements very feebly united. Sulphur has the strongest affinity for oxygen, then iodine, and lastly chlorine. But for hydrogen, chlorine has a stronger attraction than iodine, and iodine than sulphur; whence it appears that the affinity of each of those bodies for oxygen is inversely proportionate to its affinity for hydrogen.

The source of iodine in nature has been investigated with much ability by M. Gaultier de Claubry.* His first experiments were directed to the analysis of the several varieties of *Fucus*, the combustion of which furnishes the soda of sea-weeds. Before these vegetables are destroyed by combustion, he ascertained that iodine exists in them in the state of *hydriodate of potash;* and that calcination only destroys the vegetable matters, with which it is combined. As the hydriodate of potash is a deliquescent salt, it remains in the mother liquor, after separating the carbonate of soda, and most of the other salts, by crystallization. In the course of these experiments, M. de Claubry found that starch is one of the most delicate tests of the presence of iodine, and if added to any liquid containing it, with a few drops of sulphuric acid, iodine is indicated by a blue colour, of greater or less intensity. In this way, he detected iodine in the decoction of several varieties of *Fucus;* but he was unable to discover the slightest trace of it in sea-water. The *Fucus Saccharinus* yielded it most abundantly; and in order to obtain it by the cheapest and easiest process, he recommends that we should submit this *fucus*, dried and reduced to powder, to distillation with sulphuric acid.

CHAPTER XIX.

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. Only seven or eight were known to the ancients; but the class has been enlarged, within the last century, by the discovery of more than twenty new ones. In addition to the recently discovered bases of the alkalies and earths, the following appear to have a sufficient claim to be considered as distinct metals.

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

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* Ann. de Chim. xciii. 75, 113.

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 alkalies 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. It may be questioned, whether the metals are heavier, in consequence of the greater specific gravity of their individual atoms, or from a greater number of atoms being aggregated into a given volume. The former, however, is most probably the case, though it must be acknowledged that their specific gravity is by no means *exactly* proportional to the weight of their atoms.

2. They are opaque, at least in the state in which they generally occur to our observation. Gold, however, beat into leaves 1-280000th 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 proportionate 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 electri-

city. 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 1-282020th part of an inch. All the metals, however, are not malleable. Gold, platinum, 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 *semi-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 Guyton Morveau, the following are the utmost weights, which wires of 0.787 of an English line in diameter can support without breaking.

			lbs. decl. avoird. parts.
A wire of	iron	supports	549.250
———	copper	———	302.278
———	platinum	———	274.320
———	silver	———	187.137
———	gold	———	150.753
———	zinc	———	109.540
———	tin	———	34.630
———	lead	———	27.621†

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

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.

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* Nickel on the authority of Richter

† 71 Ann. de Chim. 182.

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 platinum itself, which does not melt at a less heat than 170° of Wegdwood, has been 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 other metals 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 accommodate 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, according 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 oxygen 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

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* Annales de Chimie, lxix. 92.

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 expressions 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 Sir H. 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 variously coloured oxides. In some instances, the process is accompanied with so abundant an extrication of light and heat, as to exhibit a vivid inflammation. This happens, chiefly, with some of the volatile metals. Arsenic and zinc, for example, 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.

To convert the metals into oxides, there is a *degree* of heat, which is peculiar to each metal, and even to different oxides of the same metal. Mercury, for example, is oxidized, at a degree of heat, which produces no change on iron; and lead at one degree of temperature becomes minium, at another massicot.

3. With the exception of mercury, the metals, which have been called perfect (comprehending, also, gold, platinum, silver, and palladium), 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 undergoing any change. That they have an affinity, however, for oxygen, 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 powerful 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 oxidized by oxygen gas. In many cases a metal, which undergoes this change slowly and invisibly by the action of air, takes fire in oxygen gas, and exhibits a bright inflammation. For example, it has already been shown, that an iron wire may be entirely and vividly consumed 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 affinity 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 manifest a powerful affinity for that basis, and, generally speaking, to those which are most efficient in decomposing atmospherical air. The newly discovered metals of Sir H. Davy decompose it with a rapidity, which amounts to actual inflammation; but, in general, the change is slow at common temperatures. Iron filings, for example, 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.

Water, it is observed by Gay Lussac, has the power of bringing all metals, on which it is capable of acting alone, to the same degree of oxidation as when assisted by the action of acids, sometimes to a higher degree, but never to an inferior one. Thus water by itself oxidates tin to the *maximum*, and iron and potassium to the *medium;* but mingled with acids, it oxidates iron and tin to the *minimum*.

II. All those acids in which oxygen has been proved to exist, and especially those which Dr. Thomson 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 (except the oxymuriatic, the presence of oxygen in which is still a subject of controversy) 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 and nitro-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 last acid; 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, when concentrated, 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 difficult to calculate how much oxygen the metal has acquired; since every 100 cubic inches of hydrogen gas indicate the transference to the metal of about 17 grains 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 its weight 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 oxidized 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 seldom quite pure, but almost always contains a portion of the metal, which has caused the precipitation.

From an attentive examination of facts of this kind, Lavoisier has deduced 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, to become soluble, the same quantity of oxygen as 100 grains of silver; and, therefore, as 100 to 135, so is the quantity necessary to render soluble 100 grains of mercury, to that necessary for the solution of 100 grains of silver. 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 it has been conceived by M. Frere de Montizon, that a relation exists between the specific gravity of the metals, and the quantity of oxygen, with which they are capable of uniting, the oxygen being either a multiple or submultiple of the density.* Thus the specific gravity of manganese being 7, the oxygen of the protoxide is by experiment 28.1, which is very nearly a multiple of the density by 4. The law, however, cannot be considered as sufficiently established. If it were to hold good universally, it would indicate the existence of a relation between the density of metals and the weight of their atoms.

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 29.5 grains to 100 grains of metal, composes a *black* oxide; and with 43.5 parts of oxygen to 100 of metal, it constitutes 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

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* Ann. de Chim. et Phys. vii. 7. Thomson's Ann. xii. 8.

habitudes with respect to the acids. Thus the black oxide of iron readily unites with muriatic and sulphuric acids; but the red oxide less easily. The salts with base of the first oxide 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 a great variety of 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 all 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 atomic 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. 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.
The white muriate of . . .	100	copper.
	12.28	oxygen.
	41.59	acid.

The same law appears, also, from the experiments of Sir H. Davy, to hold good with respect to the oxides of potassium and sodium. 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, a given weight of the oxide of A will neutralize twice as much of any acid as an equal weight of the oxide of B.

The solubility of the metallic salts in water, it has been observed by Gay Lussac, bears a proportion to the quantity of oxyen 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 oxidizement, 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 considerable less quantity.

An important law has been deduced by Berzelius[†] from the comparison of a great number of facts; viz. that in all neutral salts, the oxygen of the acid is a multiplication of that of the base by some entire number. The law, he apprehends, may be expressed more generally in the following terms. *When two oxidated substances enter into a neutral combination, the oxygen of that, which, in a galvanic circle, would be attracted to the positive pole, is a multiplication, by an entire number, of the oxygen of that, which would be deposited at the negative pole.* For example, 279 parts of protoxide of lead contain 19.95 parts of oxygen, and saturate 100 parts of sulphuric acid, which contain 59.85 parts of oxygen. Now the oxygen of the oxide $19.95 \times 3 = 59.85$, which is precisely the oxygen of the acid. The same coincidence holds good in a variety of other instances.

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 further 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

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[*] Mémoires d'Arcueil, ii. 159; or 37 Phil. Mag. 200.

[†] 79 Ann. de Chim. 127.

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 oxides ready formed, are also, in several cases, dissolved by liquid alkalies. 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 séparate form, is dissolved by the alkali. When alkaline carbonates are employed instead of pure alkalies, for the precipitation of metallic solutions, the oxide combines with carbonic acid, and appears in the state of a metallic carbonate.

The compounds of ammonia with metallic oxides are of more importance than those of the other alkalies, and have obtained the generic name of AMMONIURETS. They may be formed, either by acting on the metals with liquid ammonia, the water in which is decomposed, and furnishes a metallic oxide, which unites with the alkali; or they may be produced, by exposing the oxides to ammoniacal gas, at the temperature of the atmosphere. At least fifteen oxides, or rather hydrated oxides, may be brought into combination with ammonia, viz. oxides of zinc; deutoxide of arsenic; both the oxides of copper; oxide of silver; tritoxide and tetroxide of antimony; oxide of tellurium; protoxides of nickel, cobalt, and iron; peroxide of tin; deutoxide of mercury; and deutoxides of gold and platinum.

The ammoniurets are decomposed by a strong heat; the oxygen of the oxide uniting with the hydrogen of the alkali, and the azote of the latter being set free. In some cases, as in that of ammoniuret of gold, this decomposition is attended with a loud explosion.

The oxides, existing in metallic solutions, are decomposed by inflammable substances. Light only is sufficient for the decomposition of some of them. Hydrogen gas, charcoal, sulphur, phosphorus, and the compounds of hydrogen with the last three bodies, when brought into contact with the solutions of perfect metals at common temperatures, attract the oxygen from the metal, and occasion 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 employed 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 the metal in a coherent mass, and not in the small grains which would otherwise 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 nomenclature, 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 sufficiently express the characteristic distinctions of the several oxides of the same metal. 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 state 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 black and red oxides of iron; and the black and red oxides of mercury. In some instances, 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 (supposing that the proportions of oxygen and metal in each are definite) 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 was 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 submuriate 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.

The following Table exhibits, at one view, the composition of most of the metallic oxides.

Table showing the Proportions of Oxygen with which the Metals combine.

Metals.	No. of Oxides.	Colour of Oxides.	100 of Metal take Oxygen.	Authority.
Gold	1	Brownish black	10.01	Oberkampf.
Platinum	1	Black	8.287	Berzelius.
	2	. .	16.38	
Palladium	1	. .	14.209	Ditto.
Rhodium	1	. .	6.71	Ditto.
	2	. .	13.42	
	3	. .	20.13	
Iridium	1	Blue	. .	Tennant.
	2	Red	. .	
Silver	1	Olive	7.925	Berzelius.
Mercury	1	Black	4	Thenard.
	2	Red	8	
Copper	1	Red	12.5	Proust and Berzelius.
	2	Black	25.	
Iron	1	Black	29.5	Berzelius.
	2	Red	44.25	
Tin	1	Grey	13.5	Gay Lussac.
	2	White	27.	
Lead	1	Yellow	7.70	Berzelius.
	2	Red	11.08	
	3	Puce	15.60	
Nickel	1	Ash grey	27.	Tupputi.
	2	Black	unknown	Thenard.
Zinc	1	White	24.41	Gay Lussac.
Bismuth	1	Yellow	11.28	Lagerhielm.
Antimony	1	Dull white	18.60	Berzelius.
	2 (acid)	Snow white	27.90	
	3 (acid)	Yellow	37.20	
Arsenic	1 (acid)	White	34.93	Dr. Thomson.
	2 (acid)	Ditto	52.4	
Cobalt	1	Blue	19.8	Proust.
	2	Black	33.25	

Metals.	No. of Oxides.	Colour of Oxides.	100 of Metal take Oxygen.	Authority.
Manganese	1	Green	14.05	Dr. John.
	2	..	28.10	Berzelius.
	3	..	42.16	
	4	Black	56.21	
Molybdena	1	Blue	34.	Bucholz.
	2 (acid)	White	50.	
Tellurium	1	Yellowish	20.5	Klaproth.
Tungsten	1	Black	..	Bucholz.
	2 (acid)	Yellow	25.	
Uranium	1	Black	..	Ditto.
	2	Yellow	25.	
Titanium	1	Blue	..	Vauquelin.
	2	Red	..	
	3	White	..	
Tantalum	..	White	..	
Cerium	1	White	17.41	Hisinger.
	2	Fawn	26.115	

Many of the metallic oxides have an attraction for water, which they manifest by being soluble in it, or by reducing it to a solid, or gelatinous form. The soluble oxides are potash, soda, barytes, strontites, and lime; the deutoxide of arsenic, and the oxide of osmium. There are a few others, which are soluble in a very small degree, no exceeding one-thousandth of the weight of the water, viz. oxide of molybdena, deutoxide of mercury, tritoxide and tetroxide of antimony.

The compounds of oxides and water, in which the latter exists in a condensed state, are termed HYDRATES, or HYDRO-OXIDES, or HYDROXURES. The hydrates of potash, soda, and barytes retain the water which constitutes them such, at the temperature of ignition, and it can only, indeed, be expelled by bodies that have a stronger affinity for the alkali or earth. The hydrates of the remaining earths are decomposed by the heat of ignition. The hydrated oxides of the common metals are obtained, by adding a solution of pure potash, soda, or ammonia, to the solution of the oxide in sulphuric, muriatic, or nitric acid. The precipitate, washed repeatedly with water, is to be collected on a filter; and, if dried, the heat employed must be as gentle as possible; for a slight elevation of temperature is sufficient to expel the whole water, and to leave only an oxide.

The hydrated oxides are, for the most part, much more soluble in acids than the oxides. According to Berzelius, they are definite compounds, in such proportions, that the oxygen of the water is equal in weight to that of the oxide. This principle requires, however, to be established by a greater number of facts.

Besides the important class of compounds, which result from the union of metals with oxygen, the metals are capable, also, of entering into combination with hydrogen, sulphur, chlorine, 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 potassium, arsenic, tellurium, and selenium, all of which afford compounds, 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, 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 with each metal. The same metal, also, in some instances, is susceptible of combination with different quantities of sulphur, and of affording compounds, characterized by a distinct train of properties. Thus the compound of 100 parts of iron with 58½ of sulphur is brittle and of a dark grey colour; has little or no lustre; and is attracted by the magnet. But 100 parts of iron with 117 of sulphur form a yellow compact compound; of sufficient hardness to

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[*] Annales de Chimie, xxxvii. 57.

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

strike fire with steel; and having so much lustre, as to have been often mistaken by the ignorant for gold. When different sulphurets of the same metal exist, the sulphur, in those which contain the larger proportion, is an exact simple multiple of the sulphur in those which contain the less.

The following Table exhibits the composition of several of the metallic sulphurets.

100 Parts of	*Unite with Sulphur.*	*Authority.*
Gold	24.39	Berzelius.
Platinum 1st	8.287	Ditto.
——— 2d	16.38	Ditto.
Palladium	14.209	Ditto.
Silver	14.9	Ditto.
Copper	25.6	Ditto.
Iron 1st	58.75	Ditto.
— 2d	117.	Ditto.
Tin 1st	27.234	Dr. John Davy.
— 2d	54.5	Ditto.
Lead	15.92	Berzelius.
Nickel 1st	51.5	E. Davy.
——— 2d	77.	Ditto.
Zinc	48.84	Dr. Thomson.
Bismuth	22.52	Lagerhielm.
Antimony	37.25	Berzelius.
Arsenic 1st	33.3	
——— 2d	75.	
Cobalt	39.8	Proust.
Molybdenum	67.	

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 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.

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* Berthollet, Annales de Chimie, xxv. 256.

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 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, 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 deoxidized 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 compounds with alkalies, 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 sul-

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[*] Vauquelin, loc. cit. 65.

[†] Berthollet, loc. cit. 256.

[‡] Vauquelin asserts, however, (Ann. de Chim. et Phys. v. 6,) that the oxides of manganese and iron are decomposed by sulphur, and that true metallic sulphurets are formed.

phur 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 alkalies. In sulphuretted oxides, it has been observed by Berzelius,† the oxygen of the oxide is to the hydrogen of the sulphuretted hydrogen, precisely in the proportion necessary to constitute water. The oxides of all metals, he adds, which have for oxygen a greater affinity than hydrogen has, may unite with sulphuretted hydrogen. In the compounds, thus produced, the metal, sulphur, hydrogen, and oxygen exist in such proportions, that the oxygen is precisely sufficient to change the sulphur into acid, the metal into protoxide, and the hydrogen into water. But if the affinity of the metal for oxygen be inferior to that of hydrogen, the oxide is then reduced, and water and a sulphuret are generated. Thus the alkalies, the earths, and protoxides of zinc and manganese, afford, with sulphuretted hydrogen, saline combinations; but the oxides of lead and copper are decomposed by it.

It had been generally supposed that metals, which have a great affinity for oxygen, and which decompose water (as manganese, iron, zinc, uranium, nickel, cobalt, &c.) are not precipitated from their solutions, by sulphuretted hydrogen, except with the concurrence of double affinities. Gay Lussac, however, has shown‡ that the compounds of these metals with the weaker acids (as the acetic, tartaric, and oxalic) are decomposed by sulphuretted hydrogen, and produce hydrosulphurets of the respective metals. When a still weaker solvent of the metal is employed, the decomposition is more easily effected. Thus the ammoniurets of iron, nickel, &c. are entirely decomposed by that gas; and this furnishes an excellent process for obtaining pure hydrosulphurets; for the alkaline hydrosulphurets, commonly employed for this purpose, are almost always contaminated with sulphur. Those metals, which are not precipitable by sulphuretted hydrogen, become so, when acetate of potash is added to their solutions.

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

† 79 Ann. de Chim. 129.

‡ 80 Ann. de Chim. 205.

III. All the metals are susceptible of combination with CHLORINE OR OXYMURIATIC ACID. When exposed to the gas in a state of minute division, produced either by filing or beating them into leaves, they combine with it, for the most part, with the appearance of combustion. But silver, lead, nickel, cobalt, and gold, unite with chlorine, without the extrication of heat and light.

The results of these combinations are differently explained in the old and the new theory. According to the former, the metal attracts oxygen from oxymuriatic acid gas; and the oxide unites with the muriatic acid. According to the new theory, the metal unites directly with chlorine; and the combustion is produced not by oxidation, but merely by the intensity of chemical action. Consistently with the former view, the products of the combustion should be called muriates. Conformably with the latter, we may either, with Sir H. Davy, designate them by terminating the Latin name of the metal in *ane* or *anea;* or (which I should prefer) we may give them the appellation, *chlorides;* or, as Gay Lussac has proposed, that of *chlorures* or *chlorurets.*

From the greater number of metallic oxides, chlorine expels the whole of the oxygen and takes its place; and when muriatic acid gas is made to act upon them water appears, and compounds are obtained resembling those formed by the direct union of the metals with chlorine.

Chlorine combines with the metals in different proportions, which are expressed in the following Table of the result of experiments, carefully made by Dr. John Davy.

Metals.	Detl. Grains. Pts.		Decl. Grains. Pts.				
Copper	60	+	32.77	. . Chlorine	=	Cuprane.
	67	+	67.20	. . Ditto	=	Cupranea.
Tin	55	+	33.40	. . Ditto	=	Stannane.
		+	67.00	. . Ditto	=	Stannanea.
Iron	29.5	+	33.60	. . Ditto	=	Ferrane.
		+	55.50	. . Ditto	=	Ferranea.
Manganese . . .	28.4	+	33.60	. . Ditto	=	Manganesane.
Lead	97.2	+	33.80	. . Ditto	=	Plumbane.
Zinc	34.5	+	34.40	. . Ditto	=	Zincane.
Arsenic	21.9	+	33.6	. . Ditto	=	Arsenicane.
Antimony . . .	42.5	+	34.60	. . Ditto	=	Antimonane.
Bismuth	67.5	+	34.20	. . Ditto	=	Bismuthane.

IV. IODINE, when heated with the metals, combines with all of them, and forms a class of compounds called, by Sir H. Davy, IODES, and by Gay Lussac, IODURES OF IODURETS. Supposing iodine in its general habitudes most to resemble sulphur, then the latter term is the most appropriate. But if iodine, as seems probable, has a closer analogy with chlorine, its compounds with metals and other combustible bodies, should be called IODIDES. They are all insoluble, and when placed in contact with water decompose it; hydriodic acid and an oxide of the metal are formed; and these last, uniting together, compose a hydriodate.

V. 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 charcoal 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*.

VI. 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.

VII. 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 in unlimited proportions; but in a few instances, it appears probable, though it is not absolutely proved, that they unite in certain proportions only.

This proposition has been ably maintained by Berzelius, as well as by Dalton. Potassium, the former observes, gives with mercury two

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* Aikin, in Philosophical Magazine.

crystallized compounds, one of which contains twice as much potassium as the other. The *arbor Dianæ* is a definite compound of silver and mercury. When zinc and copper are distilled together, a certain quantity of zinc comes over, but the rest cannot be raised by heat. From a fused mixture of antimony, iron, and copper with much tin, metallic crystals separate on cooling, containing fixed proportions of the component metals. Whenever, indeed, the new compound has an opportunity of separating from the fused mass, it appears to be formed in established proportions.

By combination, the metals undergo a considerable change of properties, and acquire new ones, not observable in 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. All 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 cases, 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 degree 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 impaired. Even two metals, which separately are both malleable and ductile, are rendered brittle by combination. This is very remarkably 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, renders the alloy quite destitute of tenacity; and an alloy of platinum, copper, and zinc, though eminently ductile and malleable, is rendered brittle by a quantity of iron not exceeding half a grain in four ounces of the alloy.† 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 satisfactory; 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 minute 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.

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* See Aikin's Dictionary, article Alloy.

† Journ. of Science, iii. 119.

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

8. The solubility of metals in acids is modified by their combination with each other. When gold is alloyed with a small proportion of silver, the latter metal is protected from the action of the nitric acid, and in order to render it soluble in that acid, it is necessary to raise its proportion to one-fourth the weight of the alloy, which constitutes the process of *quartation*. In a similar manner, in order to render tin capable of being entirely dissolved out of an alloy of that metal with antimony, it is necessary that it should constitute 20 parts out of 21 of the alloy; in which case the tin is wholly dissolved by boiling with muriatic acid, and the antimony is left untouched.*

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* include 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

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* Chaudet, Ann. de Chim. et Phys. iii. 382.

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 platinum.

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, platinum, 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, selenium, 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.

FIRST CLASS.

MALLEABLE METALS.

SECTION I.

Gold.

To obtain gold in a state of purity, one part by weight may be dissolved in three of nitro-muriatic acid (composed of one part by weight nitric, and two muriatic acids). To the clear liquid, a solution of green sulphate of iron must be added. The gold will be precipitated in the state of a fine powder, and, after being washed first with diluted muriatic acid, and then with distilled water, may be either preserved for solution in powder, or fused into a mass.

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[*] I prefer this arrangement to the one adopted by the same author in the fifth edition of his valuable work, because in the latter, bodies are removed from the class of metals, which are closely allied to them in their external as well as in their chemical characters. Thus arsenic, tellurium, and osmium, are placed, along with hydrogen, carbon, &c. among acidifiable bodies. Berzelius has divided the metals into two classes; those that are capable of forming acids, and those that act as bases. This classification, however, is liable to the objection, that tellurium when oxidized (and probably selenium) serves both as an acid and as a base. On the whole, it appears to me, that what may be called a natural arrangement of the metals is, in the present state of our knowledge, preferable to one founded on their chemical resemblances.

[†] Tantalum has lately been shown by Dr. Wollaston to be identical with columbium.

I. The external qualities of gold are the following:

1. It has an orange or reddish yellow colour; and may be brought to assume a degree of lustre inferior only to that of steel, platinum, 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 1-280000th of an inch in thickness.

4. It is considerably tenacious; for a wire only 78-1000ths of an inch diameter will sustain a weight of 150 lb.

II. Gold may be melted by a moderate red-heat; *viz.* at about 32° of Wedgwood's pyrometer. 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 burning lens, for several hours, occasioned no loss of weight. After fusion, it crystallizes in short quadrilateral pyramids.

III. Pure gold is not oxydized by exposure to heat with the access of air; but it may be brought to the state of a purple oxide by transmitting, through gold leaf or wire, either a powerful electrical or galvanic discharge.

IV. Sulphuric, nitric, and muriatic acids have separately no evident action on gold; but the last mentioned acid, Proust has observed, by long boiling with finely divided gold, dissolves a small portion.

V. The proper solvents of gold are the oxy-muriatic and nitro-muriatic acids. Oberkampf* prefers the former, because a purer solution is obtained, and one which can more easily be had free from an excess of acid. Gold leaf, introduced into chlorine gas, takes fire and burns. But if gold leaf be suspended in water, into which chlorine gas is passed, it is dissolved, and the solution may be concentrated by evaporation.

To dissolve gold in nitro-muriatic acid, Vauquelin† reverses the usual proportions, and mixes two parts by weight of muriatic acid with one of nitric. Three parts of an *aqua regia* so composed, are equivalent, he finds, to four made with the common proportions.

The solution of gold (in whatever way prepared) has an orange-yellow colour: but this, Oberkampf asserts, is owing to an excess of acid, and it passes to a brownish-red, as soon as the redundant acid is neutralized or expelled by heat. The solution should, therefore, be evaporated to dryness, and the dry mass (care being taken not to heat it too strongly) re-dissolved in water. The solution gives a purple stain to the skin, and is susceptible of crystallization.

Muriate of gold, prepared by the solution of the metal either in oxy-muriatic or nitro-muriatic acid, is decomposed by solutions of fixed alkalies, and yields a precipitate, which differs greatly in colour, according to the circumstances of the experiment. If it has a yellow colour and a styptic taste, it is a *sub-muriate.* To avoid this, it is necessary to use a considerable excess of alkali, and then the preci-

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* 80 Ann. de Chim. 140.

† 77 Ann. de Chim. 322.

pitate is of a brownish-black colour. It is this which Oberkampf considers as the true oxide of gold. It should be dried with extreme care, for too much heat drives off a part of its oxygen. The precipitation of gold from its solution by alkalies appears, however, to require farther explanation.*

VI. This oxide is decomposed entirely by heat, without passing through any inferior stage of oxidation; oxygen gas comes over; and pure gold remains. The mean of three experiments of Oberkampf shows, that 100 parts of gold combine with 10.01 oxygen; but Berzelius states the oxygen at 11.982. It is probable that this compound is the *peroxide* of gold, and that there is also a *protoxide*, with half as much oxygen as the former; but its existence has not yet been demonstrated, and at present we are acquainted with only one oxide of this metal. If no other can be proved to exist, the atom of gold must be estimated to weigh 75, for as 10 to 100, so is 7.5 to 75.

VII. It is necessary to observe, that the entire decomposition of muriate of gold is not affected by the alkalies, and that the liquor holds in solution a triple salt of gold, alkali, and muriatic acid.

VIII. A solution of pure ammonia separates from the solution by nitro-muriatic acid 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 precipitate will appear, which will be re-dissolved if too much alkali be used. Let the liquor 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 slightest friction explodes it, and serious accidents have happened from this cause.

This detonation is explained as follows: Fulminating gold is 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 fulmi-

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* See Thomson's Annals, ix. 29.

nating compounds of metallic oxides with ammonia; such as those of silver and mercury, which will be described hereafter.

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

IX. 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 muriate 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 riband, 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 riband 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.

X. Gold is precipitated from muriatic acid, in a metallic form, by a solution of green sulphate of iron. This depends on the affinity of the protoxide of iron for a farther quantity of oxygen, which it takes from the oxide of gold.

XI. When a sheet of pure 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, 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 precipitate, 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.

The composition and colour of the precipitates of gold, thrown down by muriate of tin at the minimum, have been shown, by Oberkampf, to be very variable. The colour approaches more to a violet, as the salt of tin bears a larger proportion to that of gold; and the colour, communicated by the precipitate to porcelain, has the same variable character. When the muriate of gold is in excess, the precipitate has more of a rose colour. A violet compound was proved on analysis to contain 60 per cent. of oxide of tin, and 40 of metallic gold; and one of a fine purple consisted of 20½ oxide of tin and 79½ gold.

XII. 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 scissors, lancets, and other instruments, which it protects from rust with a very small expenditure of gold.

XIII. When a current of sulphuretted hydrogen gas is passed through a solution of gold, a black precipitate falls down. This is a true sulphuret of gold, which gives up its sulphur on the application of heat. It is composed of

Gold	80.39	100.
Sulphur	19.61	24.39
	100.	124.39

The sulphuret, thus prepared, is more uniform in its composition, than that which is precipitated by alkaline hydro-sulphurets; for these contain a variable proportion of sulphur, which is thrown down along with the gold.

The sulphuret of gold is soluble in hydro-sulphuret of potash. Liquid potash takes up a part, and leaves a yellow powder, which is metallic gold. The alkaline hydro-sulphurets do not dissolve gold, however minutely divided, till sulphur is added, when probably a sulphuret of gold is formed, on which the hydro-sulphuret is capable of acting.

XIV. Gold may be combined with phosphorus, either by precipitating its solution with sulphuretted hydrogen, or, as Mr. E. Davy discovered, by heating finely divided gold with phosphorus in a tube deprived of air. It has a grey colour, and a metallic lustre; is decomposed by the heat of a spirit lamp; and contains about 14 per cent. of phosphorus.

XV. 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 latter 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 1-1920th 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.

Platinum.

I. Platinum, 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 platinum. 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 St. Domingo, and from the gold mines of Brazil. The general aspect of the ore of platinum is that of small grains or scales, of a whiter colour than iron, and extremely heavy. Various processes have been contrived for its purification;[*] 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 Carey's, No. 182, Strand, London.

II. Platinum 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; according to Sir H. Davy, at 21.3; and, according to Marquis Ridolfi, at 22.63. It may be drawn into wire about the 2000th part of an inch in diameter, and beat into very thin plates.

2. It is extremely difficult of fusion. It may be melted, however, by the blow-pipe, with the aid of oxygen gas. A globule, also, weighing 29 grains, boiled violently in the focus of a lens about three feet in diameter;[‡] and Dr. Clark, by means of the blow-pipe with compressed oxygen and hydrogen gases, has melted more than 200 grains of platinum into a single brilliant metallic globule.[§]

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 platinum 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 platinum *at the maxi-*

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[*] See Aikin's Dictionary, article Platinum.

[†] A process for purifying platinum, by the intermediation of zinc, is described by Descotils in the 64th volume of the *Annales de Chimie*, page 334, or 37 Phil. Mag. 65; and another by the Marquis of Ridolfi in Journal of Science, &c. i. 259.

[‡] 69 Ann. de Chimie, 93.

[§] Thomson's Annals, ix. 162, and x. 374.

mum, 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. It is proper, however, to state, that Sir H. Davy did not succeed in the repetition of these experiments.

Berzelius[*] describes two oxides of platinum. The protoxide is precipitated from the muriate by an excess of potash.

Its colour is black, and it consists of

Platinum	92.35	100.
Oxygen	7.65	8.287
	100.	108.287

The peroxide, according to the same chemist, has been obtained only in combination. It is composed of

Platinum	85.93	100.
Oxygen	14.07	16.38
	100.	116.38

The accuracy of this statement of the oxides of platinum has been objected to by Mr. Cooper.[†] The protoxide of platinum was obtained by him, by pouring a perfectly neutral solution of mercury (probably in nitric acid) into a dilute solution of muriate of platinum in hot water. The precipitate, a mixture of calomel and protoxide of platinum, after being carefully washed and dried, was exposed to a heat barely sufficient to raise the calomel; after which there remained an intense black powder. By distillation Mr. Cooper ascertained that this powder is composed of 100 parts of platinum + 4.517 oxygen. If this be correct, the atom of platinum must weigh 175, for

$$4.517 : 100 :: 7.5 : 175.$$

On the other hand, we have the testimony of Vauquelin, that the oxide of platinum, obtained from the sub-muriate by means of soda, contains between 15 and 16 parts in the hundred of oxygen;[‡] while the grey oxide, which enters into the composition of fulminating platinum, contains, according to Mr. E. Davy, 11.7 of oxygen in 100 of the oxide. These discordant results show that the subject requires farther investigation.

5. Platinum has the property of *welding*,[§] which belongs to no other metal but this and iron.

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[*] 87 Ann. de Chim. p. 126.

[†] Journ. of Science, &c. vol. iii.

[‡] Ann. de Chim. et Phys. vol. v.

[§] 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.

6. It is not acted on by any other acid than the nitro-muriatic and oxy-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 reddish-coloured solution is obtained, which gives a brown stain to the skin.

When this solution is evaporated, and heated to whiteness, chlorine gas is disengaged, and may be collected in a proper apparatus. The dry compound, investigated by Mr. E. Davy, gave 18.5 per cent. of chlorine; but this is considered by him only as an approximation. From the experiments of Vauquelin, it seems probable that beside the muriate, there are also two sub-muriates, of platinum.[†] But the precise nature of these compounds is open to farther investigation.

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

8. The muriate of platinum has the characteristic property of being precipitated by a solution of muriate of ammonia. By this character, platinum 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 platinum.

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

10. 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.[‡]

11. When pure potash is poured into the muriatic solution, a precipitate ensues, which is not an oxide of platinum, but a triple compound of that oxide with the alkali and acid. With soda, also, it forms a triple combination, or *soda-muriate*. This is best obtained, by adding to nitric acid, in a retort, platinum, 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.[§]

12. Muriate of platinum is decomposed by ether, and an etherized solution of platinum is obtained; which may be applied to the same uses as the similar solution of gold. It is decomposed, also, by sul-

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[*] Mr. P. Johnson has shown that platinum, by being alloyed with silver and gold, is rendered soluble in nitric acid; (40 Phil. Mag. 1.) and Mr. Cooper has established the same fact respecting the alloy of platinum with zinc and copper. (3 Journ. of Science, p. 119.)

[†] Ann. de Chim. et Phys. v. 274.

[‡] La Grange, ii. 272.

[§] Nicholson's Journal, 8vo. ix. 67.

phuretted hydrogen,[*] and a black powder is obtained, which becomes reddish-brown with an excess of the precipitant, but reassumes its black colour, on exposure to the air. Its composition cannot be investigated easily, for the sulphur passes so rapidly to the state of sulphuric acid, as, during the desiccation of the powder, to destroy the paper on which it was collected. Vauquelin asserts that it is not a simple sulphuret, but a hydro-sulphuretted oxide of platinum.[†] The direct combination of platinum and sulphur was found by Mr. E. Davy to give an infusible black powder, containing about 16 per cent. of sulphur.[‡] Vauquelin formed it by heating 10 parts of the triple muriate of ammonia and platinum with 20 parts of sulphur, or by a similar treatment of one part of finely divided platinum, with two of sulphur. He agrees with Mr. Davy as to the proportions of its elements.

Phosphorus and platinum may be united, either by passing phosphuretted hydrogen into a solution of the muriate; or, according to Mr. E. Davy, they combine directly in exhausted tubes with vivid ignition. The result is a bluish grey powder, infusible, and containing 17 per cent. of phosphorus.

13. Platinum is acted upon by fusion with nitrate of potash and with nitrate of soda, and also with pure fixed alkalies. The latter property diminishes considerably the utility of platinum as a material for crucibles.

14. The most delicate test of the presence of platinum is muriate of tin. A solution of platinum, 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.

15. Platinum combines with potassium and sodium, and affords brittle compounds. It unites also with most metals.[§] In the proportion of only one-sixteenth it renders gold pale; it amalgamates with mercury; and diminishes the fusibility of the fusible metals. Its alloys, however, have been but little investigated.

16. A fulminating compound of platinum, analogous in its composition and properties to *aurum fulminans*, has been prepared by Mr. E. Davy, by precipitating a solution of sulphate of platinum with a slight excess of pure ammonia.[‖] The precipitate thus obtained was washed, and dried sufficiently to separate it from the filter. It was then put into a Florence flask with a solution of pure potash, and the fluid boiled nearly to dryness. A quantity of water was then added, and the solid matter, after being well washed was dried for several days at the temperature of 212° Fahrenheit.

The powder thus prepared has different shades of colour, from a light brown to a dark chocolate, and even almost black. One grain, laid on a thin sheet of copper, and heated to 400° or 420° Fahrenheit, produces

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[*] Berzelius.

[†] Ann. de Chim. et Phys. v. 263.

[‡] See his Memoir on some of the Combinations of Platinum, Phil. Mag. vol. xl.

[§] See Darcet on the Alloys of Platinum with Silver. 89 Ann. de Chim. 135.

[‖] Phil. Trans. 1817.

a report louder than that of a pistol, and the copper is deeply indented. Like fulminating gold, it is incapable of being exploded by percussion. It appears to be a triple compound of oxide of platinum, ammonia, and water.

17. Platinum has been discovered by Dr. Wollaston to be a remarkably slow conductor of caloric. When equal pieces of silver, copper, and platinum, were covered with wax, and heated at one end, the wax was melted 3½ inches on the silver; 2½ on the copper; and 1 inch only on the platinum. 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 platinum 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.*

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.

To obtain silver in a state of purity, Mr. Donovan recommends, that 240 grains of standard silver be dissolved in as much pure nitric acid of specific gravity about 1.2, as will be barely necessary for solution. This is to be filtered, and distilled water allowed to run through the filter, until the fluids amount to two ounce measures. A bright plate of copper weighing upwards of 64 grains is to be immersed and frequently agitated in it. When the silver has entirely precipitated, which will very soon happen, the clear supernatant liquor is to be poured off, and the precipitate to be well washed with pure water. The silver is then to be boiled for a few minutes in liquid ammonia. It is then to be well washed with water and dried in a filter; after which, if required, it may be melted in a crucible.†

The chemical properties of silver 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.

By transmitting a Galvanic or electric discharge through silver wire, it is oxidized; and by long exposure of silver to heat, with

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* Nicholson's Journal, xxii. 148.

† Phil. Magazine, xlvii. 205.

free access of air, it is at length converted into an olive-coloured glass. The oxide of silver may, also, be obtained by decomposing nitrate of silver with solution of barytes; and, after washing the precipitate sufficiently, heating it to dull redness. It has an olive colour, and is composed, according to Sir H. Davy, of 100 parts of silver united with 7.3 oxygen, or, according to Dr. Wollaston, 7.4. A larger proportion of oxygen is assigned by Berzelius, viz.

Silver	92.67	100.
Oxygen	7.33	7.925
	100.	107.925

No other oxide of silver has been ascertained to exist; but from the experiments of Mr. Faraday, there seems reason to believe that the pellicle, which forms spontaneously on an ammoniacal solution of oxide of silver exposed to the air, is a protoxide of that metal, in which the oxygen is to the silver as 7.5 to 157.4.*

II. Silver 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. 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 at a minimum. This subnitrate, he observes, possesses different properties from the common one.†

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. part v.) If fused by a gentle heat, it forms a semi-transparent mass of the consistence of horn, called luna cornea, or horn silver, or more properly *fused muriate of silver*.

The composition of fused 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.

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* Journ. of Science, iv. 270.

† Nicholson's Journal, xv. 376.

	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
———— Berzelius	19.035	80.965

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, after being 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 Marcet, Gay Lussac, and Berzelius, 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. Silver combines with chlorine, when heated in that gas, and a compound results, which, in composition, agrees with fused muriate of silver. According to the new theory of chlorine, it is, in fact, a compound of that body and metallic silver; and it has, therefore, been called by Sir H. Davy, *argentane*, by Gay Lussac, *chlorure of silver;* but its appropriate name is *chloride of silver*. Sir H. Davy makes the chlorine in this compound amount to 24.5 per cent., and 100 grains should therefore consist of

Silver	75.5	100.
Chlorine	24.5	32.5
	100.	132.5

Dr. Ure finds that 100 chlorine combine with 307.5 silver,* which scarcely differs from the foregoing statement. According to Dr. Marcet's analysis, 100 grains should contain 75 of silver, for this is the quantity of metal in 80.95 grains of the oxide, taking the oxygen at 7.3 to 100 of silver. If this be admitted, 100 of silver will then be saturated by very nearly 33.5 of chlorine. It must be obvious, that, in order to convert the old statement of the composition of horn silver into the new one, it is only necessary, to suppose the oxygen taken from the oxide, and added to the muriatic acid, which gives the quantity of chlorine.

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* Thomson's Annals, x. 277.

VI. 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 extreme 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 transferring 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.

VII. 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

Silver	64	70
Oxygen	6	
Nitric acid		30
		100

This statement, however, cannot be correct, as it assigns too large a proportion of oxygen to the oxide, viz. 8.6 to 100 grains of silver.

VIII. 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. The first part of the deposit, Gay Lussac finds, is perfectly pure silver. The latter portions contain an admixture of copper, which may be removed by a fresh solution of nitrate of silver. If a little mercury be poured into a bottle filled with the solution of nitrate of silver, 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 mercury 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.

IX. 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.

X. 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, in which it may remain for ten or twelve hours. 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. It may be formed, also, by boiling any precipitated oxide of silver, for a few moments, in a mixed solution of potash and ammonia. The protoxide, however, described by Mr. Faraday, does not afford it. 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.*

XI. 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.† 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, cause 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 of this substance, and in experiments on its detonation, much caution is necessary; and only very small quantities should be employed. This preparation was originally discovered by Mr. E. 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.

XII. A very useful solvent of silver has been discovered by Mr. Keir of Birmingham. It is formed by dissolving one part of nitre in

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

† Nicholson's Journal, xviii. 140.

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.

XIII. Phosphate of silver is a compound of some importance, from its use in preparing chloric acid. To obtain it, crystals of nitrate of silver, may be dissolved in pure water, and a solution of phosphate of soda be added. The neutrality of the nitrate of silver is destroyed, and though the phosphate contains an excess of alkali, the resulting liquor is acid. The precipitate is of a yellow colour. When washed and dried, it is fusible at a red heat without any farther loss of weight. It consists, according to Berzelius,* of

Phosphoric acid . . .	17.025 . . .	100.
Oxide of silver	82.975 . . .	487.38
	100.	

XIV. Silver is acted on by sulphurets of alkalies, 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. Sulphuret of silver has been analyzed by Berzelius, and found to consist of

Silver	87.032	100.
Sulphur	12.968	14.9
	100.	114.9

XV. 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. Silver of commerce is composed of 37 parts of fine silver to 3 of copper; but the fine silver, being obtained by cupellation, contains gold, which is left after solution by acids, either in the form of purple protoxide, or black peroxide.

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* Ann. de Chim. et Phys. ii. 168.

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 (which may be obtained, with less trouble, by decomposing calomel with solution of potash), is distilled in a glass retort, oxygen gas is evolved; or if a moderate heat be long continued, it acquires a reddish colour, and a still farther dose of oxygen. The black or protoxide consists, according to Fourcroy and Thenard, of 100 parts of metal united with 4 of oxygen. The protoxide of mercury, it is asserted by Guibourt, cannot be obtained perfectly pure; for when either pronitrate or protochloride of mercury is decomposed by potash, the precipitate, even when excluded from air, contains peroxide of mercury and small globules of metal, the latter of which are discoverable by a magnifier. Nor can it be procured by triturating together the peroxide and metal.*

(*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 brownish red, or flea colour. This red oxide was formerly called *precipitate per se*.

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* 6 Ann. de Chim. et Phys. ii. 422.

When distilled alone in a glass retort, it yields oxygen gas, and returns to a metallic state. It is composed, according to Fourcroy and Thenard, of 100 metal and 8 of oxygen. Sir H. Davy, also, finds its oxygen to be exactly double that of the *protoxide*, which is composed of 190 mercury and 7.5 oxygen, while the peroxide consists of 190 metal and 15 oxygen. Hence the protoxide is composed of

Mercury	96.22	100.
Oxygen	3.78	3.947
	100.	103.947

And the peroxide of

Mercury	92.69	100.
Oxygen	7.31	7.894
	100.	107.894

It will be sufficiently near the truth, if we admit, with Dr. Wollaston, the black oxide to consist of 100 metal, united with 4 of oxygen, and the red of 100 mercury + 8 oxygen. The latter number agrees with the experiments of Guibourt; and the oxygen in the protoxide, though from his analysis it appeared to contain 4½ in 100 mercury, may be safely taken at half that in the peroxide. This would make the atom of mercury to weigh 175, for

4 : 100 :: 7.5 : 175.

Peroxide of mercury, Guibourt finds, is decomposed by long continued exposure to light. It is soluble in water, and communicates to it the property of turning syrup of violets green, and of being precipitated by sulphuretted hydrogen. With ammonia, the peroxide forms an *ammoniuret*, decomposed by heat.

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 super-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 times its weight 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 of *pro-nitrate of mercury*. The solution does not become milky when mingled with water. Pure fixed alkalies 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, *constituting per-nitrate of mercury*. 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 *nitroxide of mercury;* because it contains a small proportion of acid.

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[*]. This powder has the property of detonating loudly in a gentle heat, or by light friction.

VIII. There are two views under which we may regard the salts, heretofore considered as compounds of oxide of mercury with different proportions of muriatic acid; for it is possible that they may, in reality, be compounds of metallic mercury with different propor-

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[*] See Philosophical Transactions, 1800, page 214.

tions of *chlorine*, for which the proper appellation is *chlorides*. Mercury, according to the former view, though not acted upon by muriatic acid, may be brought into union with that 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 *muriate of mercury*, or the *corrosive sublimate* of the shops. The same components, with a still farther addition of mercury, constitute an insoluble substance called *sub-muriate of mercury* or *calomel.*

The corrosive muriate requires 16 or 20 times its weight of water for solution; but is soluble in about one and one-eighth its weight of alcohol. Its solution in water is decomposed by all the fixed alkalies and alkaline salts, which throw down at first an orange, and afterwards a brick red precipitate.

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 repeatedly washing with water. Fourcroy and Thenard have given the following comparative view of the composition of corrosive sublimate and calomel.

Calomel . . .	100.	mercury.
	4.16	oxygen.
	13.97	muriate acid.

Corrosive Muriate	100.	mercury.
	8.21	oxygen.
	27.39	muriatic acid.

Mercury unites directly with chlorine, and, if heated in the gas, burns with a pale red flame. The product is identical with corrosive sublimate, which, according to Sir H. Davy, is a compound, not of muriatic acid and oxide of mercury, but of chlorine and that metal. According to his experiments, calomel or *protochloride of mercury*, consists of 190 mercury and 33.5 chlorine, or of

Mercury	85	100.
Chlorine	15	17.6
	100	

And corrosive sublimate or *perchloride of mercury*, is composed of

Mercury	74	100.
Chlorine	26	35.2
	100	

The oxides of mercury are soluble in chloric acid;[*] and, as is the case with their combinations with chlorine, the salt formed with the peroxide is by much the more soluble. When heated, they give out oxygen gas, and are converted into peroxide of mercury and corrosive sublimate. They may be called *protochlorate* and *deutochlorate* of mercury.

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 fusion, and afterwards sublimed, they constitute a red sulphuret called 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 4th volume of the *Annales de Chemie*, or in Aikin's Dictionary, vol. ii. This compound also may be obtained by mixing concentrated solutions of muriate of mercury and hydro-sulphuret of ammonia. 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.[†]

If mercury, like other metals, unite with twice the quantity of sulphur which it absorbs of oxygen, the proportion of ingredients on its sulphurets will be found by doubling the oxygen of the oxides, and they will be composed as follows:

	Mercury.	Sulphur.
Proto-sulphuret	100 . . .	7.894
Per-sulphuret	100 . . .	15.788

The composition of the sulphurets of mercury has been investigated experimentally by Guibert, with results very nearly approaching to these theoretical quantities.[‡] The first he obtained by acting

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[*] Vauquelin, 95 Ann. de Chim. 103.

[†] Nicholson's Journal, 8vo. i. 299.

[‡] Ann. de Chim. et. Phys. ii. 425.

on calomel; and the second on corrosive sublimate, with sulphuretted hydrogen. Both the resulting compounds were black; but the latter was entirely convertible into cinnabar of the usual colour by sublimation. Analysis, by distillation with iron, showed them to consist as follows:

	Mercury.	Sulphur.
Proto-sulphuret	100 . . .	8.2
Per-sulphuret	100 . . .	16.0

SECTION V.

Rhodium and Palladium.

The discovery of these two metals was made by Dr. Wollaston, who separated them from the ore of platinum, by the following process.

I. Rhodium. When a solution of the ore of platinum 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 platinum, 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 nitro-muriatic acid; and to the solution, when completed, add a portion of muriate of soda, equivalent in weight to about one-fiftieth the ore of platinum employed. Evaporate by a gentle heat. The dry mass contains the soda-muriates of platinum, palladium and rhodium; the two former of which may be separated by alcohol, and the salt of rhodium will remain. From its solution the rhodium may be precipitated by zinc, which throws down a black powder, amounting, in weight, to four grains from 400 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 hydrosulphuret of ammonia. The carbonated alkalies produce no change; but the pure alkalies precipitate a yellow oxide, soluble in all acids that have been tried.

Berzelius has ascertained the existence of three oxides of this metal, composed as follows:

	Metal.		Oxygen.
Protoxide	100	+	6.71
Deutoxide	100	+	13.42
Peroxide	100	+	20.13

II. Palladium. 1. The alcoholic solution (I. 1.) contains the soda-muriates of palladium and platinum. The latter metal may be precipitated by muriate of ammonia; and may be obtained from the remaining liquid palladium, 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 platinum in nitro-muriatic acid, neutralized by evaporating the redundant acid, or by adding an alkali, and either before or after the separation of the platinum 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.

3. Vauquelin has, also, proposed a method of separating rhodium and palladium from the ore of platinum. His process, which is less simple than the second method of Dr. Wollaston, is described at length in the 4th and 7th volumes of Dr. Thomson's Annals of Philosophy.

On examining some ore of platinum, brought from the gold mines of Brazil, Dr. Wollaston has lately discovered in it small fragments of *native palladium*, which appear to be free from admixture with every other metal, except a very minute portion of iridium. These

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

fragments differ from the grains of platinum, in being formed of fibres, which are in some degree divergent from one extremity. This external character Dr. Wollaston deems sufficient for distinguishing the metal in situations, where recourse cannot be had to experiment.*

Mr. Cloud, assay master of the American mint, has, also, discovered palladium in a native alloy of gold with that metal.† The alloy contained no other metal, and was perfectly free from its common ingredients, copper and silver.

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

4. The following are the properties of palladium:

(*a*) Its colour resembles that of platinum, 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 platinum, which it rather surpasses in expansion 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 melted 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 platinum; and is malleable to a great degree.

Berzelius has shown that 100 parts of palladium unite with 14.209 parts of oxygen. Hence the oxide consists of

Palladium	87.56
Oxygen	12.44
	100.

(*c*) Palladium readily combines with sulphur. The compound is whiter than the separate metal, and is very brittle. It has been investigated by Berzelius, and shown to be composed as follows:

Palladium	78.03	100.
Sulphur	21.97	28.15
	100.	128.15

(*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 bluish 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.

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* Philosophical Transactions, 1809.

† 74 Ann. de Chim. 99.

(*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. From these solutions, potash throws down an orange coloured precipitate, which is probably a hydrate.

(*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 alkalies and earths. These precipitates are mostly of a fine orange colour; are partly dissolved by some of the alkalies; 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 platinum; but the precipitates from nitrate of palladium have generally a deeper shade of orange. All the metals, except gold, platinum, 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 succeeds, 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. Hydrosulphurets, 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 platinum, of destroying the colour of gold, even when in a very small proportion. Thus one part of platinum, or palladium, fused with six of gold, reduces the colour of the gold nearly to that of the white metal employed.

Dr. Wollaston has furnished an alloy of gold and palladium for the graduation of the magnificent circular instrument, constructed by Mr. Troughton, for Greenwich observatory. It has the appearance of platinum, and a degree of hardness, which peculiarly fits it for receiving the graduations.

SECTION VI.

Iridium and Osmium.

When the ore of platinum 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 separated spontaneously in thin dark-coloured flakes. The acid solution contained both metals also; but principally one, which is not altered 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 oxidation. From this property Mr. Tennant terms it IRIDIUM. The proportion of oxygen in its oxide still remains to be determined.

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, carbonate 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 platinum, precipitated 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. But Mr. Children has since fused it by his immense galvanic battery into a metallic globule, which was white, very brilliant, and, though porous, had the high specific gravity of 18.68.* It did not combine with sulphur or arsenic. Lead united with it, but was separated by cupellation. Copper, 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 simply 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, somewhat resembling that of chlorine gas, from which property its name has been

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* Phil. Trans. 1815, p. 370.

derived. The watery solution 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.

M. Laugier having observed that nitro-muriatic acid, which has been employed to dissolve platinum, emits a strong odour of osmium, distilled the liquor, and saturated the product with quicklime; after which, by again distilling the liquid, he obtained a quantity of osmium sufficient to repay the trouble of the process.*

2. The oxide of osmium, the precise composition of which is unknown, gives up its oxygen to all the metals, excepting gold and platinum. 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 excess 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 platinum. The specific gravity of this ore is about 19.5, and therefore exceeds that of crude platinum itself, which is only 17.7. The grains are about the size of those of crude platinum, but are considerably harder; are not at all malleable; and appear to consist of laminæ, possessing a peculiar lustre.

The discovery of Mr. Tennant, if it had required any confirmation,

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* 89 Ann. de Chim. p. 191.

has lately received it from an elaborate investigation of Vauquelin, whose memoir is published in the 89th volume of the Annales de Chimie, and in the sixth volume of Dr. Thomson's Annals.

SECTION VII.

Copper.

Copper, according to Berzelius, as it is found in commerce, is always contaminated with a little charcoal and sulphur, amounting to about one half of a grain in 100 grains. Lead, antimony, and arsenic are also occasionally found in it.[*] To fit it for the purposes of accuracy, it may be dissolved in strong muriatic acid; and, after adding water, may be precipitated from the solution by a polished plate of iron. The metal, thus obtained, should be washed, first with diluted muriatic acid, and then with water, and may either be fused, or kept in a divided form.

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 compound holds carbonic acid in combination. The oxides of copper 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 stage the compound is red; when oxidated to the maximum, it is black.

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[*] 47 Phil. Mag. 206.

The *black* or *peroxide* 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	100
Oxygen	20	25
	100	

To prepare the *protoxide* Mr. Chenevix recommends the following process. Mix together 57½ 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 400 parts of 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 (or rather hydrated protoxide) of copper is precipitated of an orange colour. This oxide, when deprived of water, becomes red; but it attracts oxygen so strongly that it can scarcely be dried without absorbing more. It is composed of

Copper	88.89	100.
Oxygen	11.11	12.5
	100.	

II. Copper combines with strong sulphuric acid, in a boiling heat, and affords a blue salt, called sulphate of copper. In this process, part of the sulphuric acid is decomposed, and furnishes oxygen to the metal which is dissolved. It is, therefore, better, in preparing sulphate of copper, to use the oxide obtained by calcining copper scales with free access of air. (*a*) Sulphate of copper is a regularly crystallized salt, easily dissolved by water. (*b*) The solution is decomposed by pure and carbonated alkalies. The former, however, redissolve 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 black oxide	32
Oxygen	6.4		
Sulphuric acid			32
Water			36
			100

Exclusive of water of crystallization, Berzelius,* from his own analysis, states its composition at

Peroxide of copper	50.90	103.66
Sulphuric acid	49.10	100.
	100.	

Proust described a *subsulphate of copper*, formed by adding solution of potash to a solution of the above sulphate. Berzelius prepared it by the cautious addition of ammonia, and found it, on analysis, to be composed of

Peroxide of copper	80	100
Sulphuric acid	20	25
	100	

Including its water of composition, the subsulphate consists of

Sulphuric acid	21.28
Peroxide of copper	64.22
Water	14.50
	100.

No sulphate of the protoxide is yet known; for when sulphuric acid is brought into contact with the protoxide, one half of the oxide gives up its oxygen to the other half, which thus becomes peroxide and unites with sulphuric acid.

Sulphite of copper may be obtained by transmitting a current of sulphurous acid gas, (which has been first passed through a small quantity of water, in order to deprive it of sulphuric acid) into a vessel containing water and peroxide of copper. A green liquid is formed, which contains sulphite of copper, with a large excess of acid; and sulphite of copper, in very small red crystals, remains at the bottom of the vessel. This salt has been investigated by Chevreul;† and found to consist of

Protoxide of copper	63.84
Sulphurous acid	36.16
	100.

III. Copper exposed to a damp air rusts, and becomes covered with sub-carbonate of copper. The same compound is still more rea-

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* 77 Ann. de Chim.

† 88 Ann. de Chim. 181.

dily produced by adding carbonated alkalies to the solutions of copper. The nitrate of copper, precipitated by carbonate of lime, affords a blue precipitate, called *Verditer.* This substance is nearly allied to the native blue carbonate in the nature and proportion of its ingredients. It consists of

Water	5.9
Carbonic acid	24.1
Peroxide of copper	67.6
Moisture and impurities . .	2.4
	100.*

Berzelius observes that subcarbonate of copper differs greatly in appearance when precipitated from a cold and from a hot solution. In the latter case its colour is yellowish green; in the former, it is bluish green, and much more bulky. It is composed of

Peroxide of copper	71.7
Carbonic acid	19.7
Water	8.6
	100.

IV. Copper dissolves readily in diluted nitric acid; and nitrous gas, holding a little copper in solution, is evolved in great abundance. The solution at first is green and muddy; but by degrees, a yellow precipitate falls to the bottom, and the liquid becomes transparent and blue. By evaporation, it yields a salt, which has the 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 per-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 filter, 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.

Nitrate of copper is decomposed, but not entirely, by carbonated alkalies; for, after their full effect, Berzelius found that a precipitate is still occasioned, by adding water impregnated with sulphuretted hydrogen.

This salt is constituted, according to Berzelius, of

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* R. Phillips, Journ. of Science, iv. 279.

Peroxide of copper	67.22
Nitric acid	32.78
	100.

A sub-nitrate of copper is, also, described by the same chemist.[*] It may be obtained either by carefully heating the nitrate; or by adding a small proportion of potash or ammonia to its solution.

V. Concentrated and boiling muriatic acid acts on finely divided copper; and a green solution is obtained. In this salt the copper is oxidized to its maximum, and the salt may, therefore, be called, for the sake of brevity, *permuriate of copper*. 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

Exclusive of water, Berzelius states its composition to be

Peroxide of copper	59.8
Muriatic acid	40.2
	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 per-muriate of copper with filings of the metal, it is converted into a muriate of protoxide or *pro-muriate;* 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 per-muriate. Alkalies throw down an orange precipitate. It consists of

Copper	65.80	forming sub-oxide	73.88
Oxygen	8.08		
Acid			26.12
			100.

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[*] 82 Ann. de Chim, 250.

By the combustion of copper in chlorine gas, two compounds are produced at the same time, one of which is a fixed easily fusible substance, resembling common rosin; the other a yellowish sublimate. The first, composed of 60 copper and 33.5 chlorine, and called by Sir H. Davy *cuprane*, but more properly named *protochloride of copper*, is insoluble in water, but becomes green by exposure to the atmosphere. The second, called *cupranea*, or *perchloride of copper*, dissolves in water, and gives it a greenish colour; and is composed of 60 copper to 67 chlorine. Its solution is identical with permuriate of copper; for even though it be admitted, according to the view of Sir H. Davy, to be, when solid, a compound of chlorine and metallic copper, yet during the solution it will decompose water, and become a true muriated oxide of copper.

VI. When corroded by long continued exposure to the fumes of vinegar, copper is converted into verdegris.—The verdegris of commerce is composed partly of an acetate, soluble in water, and partly of a sub-acetate which is not soluble in water, consisting of 63 peroxide + 37 acid and water. By solution in distilled vinegar and evaporation, a salt is obtained in regular crystals, which are completely soluble in water, and which consist of 39 peroxide and 61 acid and water.—These, distilled alone, yield concentrated acetic acid, and a combination remains in the retort, containing, in 90 parts,

4.50	charcoal
78.66	copper
6.84	oxygen
90.	

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

Copper leaf, Berzelius observes,* burns in gaseous sulphur, as brilliantly as iron wire in oxygen gas. A compound is formed, precisely analogous to the native sulphuret of copper, and composed of

Copper	80	100.
Sulphur	20	25.6
	100	125.6

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* 79 Ann. de Chim. 250. See also Vauquelin on the Artificial Sulphuret of Copper, lxxx. 265.

Dobereiner, by passing sulphuretted hydrogen through a solution of copper, obtained a precipitate composed of two parts by weight of sulphur and one of copper; and by boiling peroxide of copper with an alkaline hydrosulphuret, a dark flame yellow compound was formed, consisting of equal weights of sulphur and copper.*

Copper unites, by fusion, with phosphorus. The phosphuret is white, brittle, and of the specific gravity 7.122. The analysis of Pelletier gives 20 per cent. of phosphorus.

IX. Ammonia readily dissolves the oxides and hydro-oxides of copper. Nothing more is necessary than to digest them together in a phial. The solution has 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 affords 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.* Copper may, also, be alloyed with iron; but the compound has no useful properties.†

SECTION VIII.

Iron.

Iron has a bluish white colour, and admits of a high degree of polish. It is extremely malleable, though it cannot be beaten out to the same degree of thinness as gold or silver. It is much more ductile, however, than those metals; for it may be drawn out into wire as fine as a human hair; and its tenacity is such that a wire only 78-1000th of an inch in diameter is capable of supporting a weight of nearly 550 lb. 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

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[*] Thomson's Annals, x. 148.

[†] 49. Philos. Magazine, 107.

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.

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. Lavoisier made many experiments to ascertain the increase of weight, acquired by the iron, and concluded, that on an average, 100 parts of iron condense, from 32 to 35 parts of oxygen. Dr. Thomson, however, on repeating the experiment several times, did not find that 100 parts of iron absorbed more than 27.5 of oxygen; but he observes, that it is almost impossible to collect the whole product; and that minute portions are dissipated in sparks.*

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. Priestley. In composition, it does not appear to differ from the oxide of iron obtained by the action of atmospheric air, and is strongly magnetic. By a careful repetition of the process, Dr. Thomson found that 100 grains of iron, ignited in contact with the vapour of water, acquire 29.1 grains of oxygen.

3. When iron is dissolved in diluted sulphuric acid, the acid is not decomposed; but the metal is oxidized at the expense of the water, and hydrogen gas is obtained in abundance. Now as water is composed of two volumes of hydrogen and one of oxygen, a quantity of oxygen, equal in volume to half the hydrogen gas obtained, must have combined with the metal; that is, for every 200 cubic inches of hydrogen, oxygen equal to 100 cubic inches or 33.8 grains, must have united with the metal. Dr. Thomson, from an experiment of this kind, calculated that 100 grains of iron, after the action of dilute sulphuric acid, had gained 27.5 of oxygen. It is to be considered, however, that the purity of the iron employed will materially affect the result; for if the iron contain charcoal, as is always the case, carburetted hydrogen gas will be mixed with the hydrogen; and the hydrogen in this gas being in a condensed state, the apparent will be less than the real quantity disengaged.

Iron, by the different processes which have been described, is converted into an oxide, of a black colour, and still retaining the magnetic property. Its composition has been the subject of a series of experiments by Bucholz, who concludes that 100 parts of iron, to become the black oxide, condense 29.88 parts of oxygen; Dr. Wollaston assumes the oxygen to be 29 parts, and Dobereiner makes it 30. Berzelius's determination differs but little from these, viz.

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* 27 Nich. Journ. 381.

Black oxide	Iron	77.22	100.
or protoxide	Oxygen	22.78	29.5
		100.	

When the oxide of iron, which has just been described, is dissolved in nitric acid; then boiled for some time; and, after being precipitated by ammonia, is washed, dried, and calcined in a low red heat, it is found to be converted into a red oxide. This, according to Bucholz, is composed of 100 parts of iron and 42 of oxygen; to Dobereiner of 100 iron and 45 of oxygen; or according to Dr. Wollaston of 100 metal and 43.5 oxygen; but Berzelius states its composition as follows:

Red oxide	Iron	69.34	100.
or peroxide	Oxygen	30.66	44.25
		100.	

The existence of these two oxides, and the proportions of their ingredients, at somewhere near 30 and 45 oxygen to 100 iron, are clearly established. But besides these, it has been attempted to be proved that there is another oxide of iron. Thenard contends for a compound, containing less oxygen than the black oxide, viz. 25 parts to 100 metal; a second composed of 37.5 oxygen to 100 metal; and a third of 50 to 100 metal. And Gay Lussac, also, supports the notion of three oxides with proportions, however, differing from those of Thenard. The first is that which is obtained by dissolving iron in diluted sulphuric or muriatic acid, out of the contact of air. It is precipitated white by alkalies, and by ferro-prussiates, and is composed of 100 iron and 28.3 oxygen. The second is obtained when iron is oxidized by the vapour of water or oxygen gas, and consists of 100 iron and 37.8 oxygen. The third is the acknowledged red oxide, which is composed of 100 iron and 42.31 oxygen.[*] It is probable, however, that the only known oxides are the two, the composition of which has already been stated on the authority of Bucholz, Wollaston, and Berzelius; and that the new oxide of Gay Lussac is, as Berzelius thinks, a compound of the black and red oxides.

There appear to be two hydrates or hydro-oxides, corresponding to to these two oxides of iron, which are obtained whenever we precipitate their respective solutions in an acid, by a fixed alkali. The hydrate of the black oxide is white, with a tinge of olive or green; that of the red oxide is orange coloured. The former hydrate passes to the latter, by exposure to the atmosphere. Ochre, it has been shown by Leidbeck, is a native hydrate of the red oxide, mechanically mixed with earthy ingredients; but, exclusively of them, composed of 20.2 to 25 water, with 60 to 62 oxide of iron.[†] The preparation of a pure hydrate of iron was found by Berzelius to be attended with great difficulty.

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[*] 80 Ann. de Chim. 163, and 1 Ann de Chim. et Phys. 33.

[†] 80 Ann. de Chim. 163.

It may be remarked, on comparing the composition of the two oxides of iron, that the oxygen of the red is not a multiplication of that of the black oxide by an entire, but by a fractional number; for 29.5 × 1½ = 44.25. This anomaly, as was observed in the account of the principles of the atomic system, is best got over by multiplying by 2 the numbers (1 and 1½), expressing these proportions, which will make the ratio of 29.5 to 44.25 the same as that of 2 to 3. We are thus, however, led to the supposition, that there is an oxide inferior to the black oxide in its proportion of oxygen; and which, from theory, should consist of 100 iron and 14.75 oxygen. The black oxide contains a quantity of oxygen, which is a multiplication of 14.75 by 2, and the red by 3. And if the supposed protoxide be constituted of an atom of metal and an atom of oxygen, the weight of the atom of iron will be about 50, for as 14.75 to 100 so is 7.5 to little more than 50. Dr. Thomson, in an Essay on this subject, has argued that the peroxide of iron is a compound of 2 atoms of base + 3 atoms of oxygen, the protoxide being a compound of 1 atom of each of those bodies.*

Until this difficulty is cleared up, we may, however, give the name of *protoxide* to the black oxide of iron; and the red compound of iron and oxygen may continue to be called the *peroxide.*

II. Whenever diluted sulphuric acid is made to act on iron, we obtain a compound of that acid with the protoxide. The solution, by evaporation, yields crystals, which have a beautiful green colour, and the shape of rhombic prisms, not of rhomboids, as is sometimes represented.† They have a strong styptic taste; redden vegetable blue colours; and are soluble in about two parts of cold and three-fourths their weight of boiling water. The solution is precipitated of a greenish white by alkalies, and white by prussiate of potash. The crystals, when distilled, are decomposed, and yield a strong fuming acid, called *glacial sulphuric acid.* The acid, in this salt, is to the oxide, in the proportion of 100 to 88, and it is composed, according to Berzelius, of

Sulphuric acid	28.9
Protoxide of iron	25.7
Water	45.4
	100.

When a solution of green sulphate of iron is heated with access of air, part of the protoxide passes to the state of peroxide, and, combining with a portion of acid, falls down in the form of a yellow powder, which, according to Berzelius, is a sulphate of the peroxide with *excess of base,* or a *sub-sulphate.* The acid in this compound is to the base, as 100 to 266, and it is therefore composed of

Sulphuric acid	27.33
Peroxide of iron	72.67
	100.

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[*] Annals of Phil. x. 102.

[†] Ib. xi. 284.

Other sulphates with base of peroxide of iron have been investigated by Dr. Thomson,[*] but no sulphate of protoxide with *excess* of *acid* is yet known.

The farther oxidation of the iron in the green sulphate is effected more expeditiously by boiling its solution with some nitric acid, and evaporating to dryness, care being taken not to raise the heat so as to expel the sulphuric acid. Water, added to the residuum, dissolves a salt, which is composed of sulphuric acid and peroxide. The solution has a yellowish colour; does not afford crystals; but when evaporated to dryness, forms a deliquescent mass, which is soluble in alcohol, and may thus be separated from the green sulphate. Its solution affords a blue precipitate with ferro-prussiate of potash. This salt has been called, but not with strict propriety, *oxy-sulphate.* Its legitimate name would be *sulphate of peroxide of iron;* but, as this is inconvenient from its length, it may be called the *red sulphate of iron.* It consists, according to Berzelius, of

Sulphuric acid	60.44 . . .	100.
Peroxide of iron . . .	39.56 . . .	65.5
	100.	165.5

The sulphurous acid, also, unites with iron and forms a sulphite; and this sulphite, taking an additional quantity of sulphur, composes a sulphuretted sulphite. The precise composition of these salts remains to be determined.

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 impure nitrous gas. The solution, at first, is a deep green, but when nearly saturated assumes a red colour. It is not crystallizable, but, when evaporated, forms a deliquescent mass.

The nitrate of iron, it was long ago shown by Sir H. 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 maximum.

To obtain nitrate of iron, in which the oxide is at the minimum, acid of the specific gravity of 1.25 or less must be used; the iron must be added in large pieces, and at distant intervals; and the operation carried on without the access of air. When this solution is made on a large scale for the purposes of the dyer, it is proper to connect the vessel, in which it is prepared, with a large receiver; for, in the latter, a quantity of nitrous acid will be found, which is worth the trouble of collecting. Nitrate of iron, thus prepared, passes, on exposure to the atmosphere, to the state of that in which the oxide is at the maximum. The composition of these two nitrates has not yet been accurately determined.

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

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[*] Annals of Phil. x. 102.

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.

The green muriate is convertible into the red by simple exposure to the atmosphere. Berzelius describes an interesting experiment founded on this property. If a solution of the green muriate be exposed to the atmosphere, in a tall cylindrical glass jar, for some days, and a few drops of pure ammonia be introduced at different depths by means of a tube, the precipitate formed near the surface will be green; a little lower blue; still lower greyish; then of a dirty white; and at the bottom perfectly white, if time has not been allowed for the atmospheric oxygen to penetrate so low.

When the solution of green muriate is evaporated dry, and the residuum is heated to redness, a compound is obtained which, according to Dr. John Davy's experiments, is composed of iron and chlorine. During ignition, the oxygen of the oxide and the hydrogen of the muriatic acid, are supposed to unite and form water, while the chlorine combines with the metal. The compound, termed by Dr. Davy *ferrane*, is the *protochloride of iron*. It consists of

Chlorine	53.2	100
Iron	46.8	88
	100.	188

When iron wire is burned in chlorine gas, a substance is formed of a bright yellowish brown colour, and with a high degree of lustre; volatile at a temperature a little above 212°, and crystallizing in small iridescent plates. It acts violently on water, and forms a solution of the red muriate. This is the *perchloride of iron*. It is composed of

Chlorine	66.1	100.
Iron	33.9	51.5
	100.	151.5

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

(*a*) Ferro-prussiate of iron is nearly insoluble in water.
(*b*) It is not soluble in acids.

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* The prussic acid and ferro-prussic acid (or ferruretted chyazic acid of Mr. Porrett) will be described in the chapter on Animal Substances.

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

(*d*) It is decomposed by pure alkalies and earths, which abstract the ferro-prussic acid, and leave the iron in the state of peroxide. Thus, when pure potash is digested with ferro-prussiate of iron, its beautiful blue colour disappears, and we obtain a combination of potash and ferro-prussic acid. It has been considered as a triple compound of prussic acid, potash, and iron; but, according to the new views of Mr. Porrett, it is a binary compound of ferro-prussic acid and peroxide of iron.

Mr. Porrett has ascertained its composition to be as follows:

19.33	Protoxide of iron } forming ferro-prussic acid	53.38
34.05	Prussic acid }	
	Peroxide of iron serving as a base	35.00
	Water of crystallization	11.62
		100.

In Nicholson's Journal (4to. iv. 30. 171), I have given an improved process for preparing the ferro-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 immediate production 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 reddish brown or copper-coloured sediment continues to appear. Wash this sediment, which is a ferro-prussiate of copper, with repeated effusions 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, chap. vii. sect. 4. The ferro-prussic acid will leave the oxide of copper and pass to the alkali, forming a ferro-prussiate of potash.

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 (chap. ix. sect. 1.) 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. These crystals are perfectly neutral; insoluble in alcohol; are not decomposed by boiling, or by the contact of carbonic acid; and give Prussian blue with solutions of peroxide of iron.

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 ferro-prussiate of potash is mixed with sulphate of iron, in which the metal is oxidized at the minimum, the ferro-prussiate of iron that is formed is of a white colour, but gradually becomes blue, as the iron, by exposure to air, passes to the state of peroxide.*

(*f*) The effect of a sympathetic ink may be obtained, by writing with a pen dipped in a very dilute solution of ferro-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 ferro-prussiate of potash decomposes all metallic solutions, excepting those of gold, platina, iridium, osmium, rhodium, tellurium, and antimony.†

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 a view of keeping these insoluble compounds 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.

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[*] See Proust's memoir, in Nicholson's Journal.

[†] See Proust, Philosophical Magazine, xxx. 42.

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 alkalies. 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.

Alkalies, 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 destruction 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 oxymuriatic 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 2½ 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.* 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 green sulphate of iron and phosphate of soda. A blue precipitate is formed, which is soluble in many of the acids, and precipitated without change by ammonia.

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* See Nicholson's Journal, 8vo. ii. 145.

The *oxy-phosphate* of iron is, also, an insoluble salt. It may be formed by mingling the solutions of phosphate of soda and oxi-sulphate of iron. Its colour is yellowish white. Both these preparations have lately derived some importance, from being recommended as remedies of cancer.

VIII. The succinic acid composes with iron a brown mass, insoluble in water. The combination is best effected by double decomposition, and especially by the addition of a solution of succinate of ammonia to the salts of iron. A loose brown-red precipitate of succinate of iron falls down. This precipitate Klaproth exposes to heat, first by itself, and afterwards mixed with a small quantity 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, 70.5 of metallic iron, the precipitation of a solution, by succinate of ammonia, affords a ready method 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 upon iron, and forms a solution, which is of great use in dyeing and calico-printing. The acetite of iron may, also, be obtained by a 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 occasionally shaken up, impregnate the water with this metal. This solution is decomposed by boiling, and in a less degree by exposure 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 water, 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. The best method, however, 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, and passes to the state of sulphate. (*d*) When diluted sulphuric or muriatic acid is poured on it, we obtain sulphuretted hydrogen gas.

In the 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. 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 known only as a natural product; it is not magnetic; is nearly insoluble in diluted sulphuric and muriatic acids; and gives no sulphuretted hydrogen gas with acids. But the sulphuret is readily soluble, obeys the magnet, and gives abundance of sulphuretted hydrogen with dilute acids. It is composed of

Iron	63	100.
Sulphur	37	58.75
	100	

And the super-sulphuret is composed of

Iron	53.92	100
Sulphur	46.08	127
	100.	

Though the artificial sulphuret varies in its composition, yet it is probable that these varieties are occasioned, by the sulphuret being mechanically mixed with different proportions of iron. The foregoing appear to be the only well ascertained and definite compounds; and the analysis of them by Berzelius, it may be observed, agrees very nearly with that of Proust, and indeed does not differ, in either case, one per cent. If the sulphuret be, as is consistent with all we know at present, that compound in which sulphur exists in the smallest proportion, this would be unfavourable to the notion of any oxide of iron with less oxygen than the black oxide. For in almost every other instance, the protoxide of a metal contains a quantity of oxygen equal to half the sulphur in the pro-sulphuret, a coincidence sufficiently explained by admitting both to be *binary compounds,* in the sense of the word annexed to it by Mr. Dalton, and that the weight of the atom of oxygen is just half the weight of the atom of sulphur. Gay Lussac contends for the existence of three sulphurets corresponding to his supposed three oxides of iron;[*] but the details of the experiments establishing their existence still remain to be published.

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.

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[*] 80 Ann. de Chim. 170.

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 from 1-60th to 1-140th its weight of carbon. This appears to be the only addition necessary to convert iron into steel; for though it is proved that the best steel is made from iron which has been procured from ores containing manganese, yet careful and skilful analysis discovers no manganese in steel.*

Cast or *crude iron,* besides casual impurities, contains oxygen, carbon, and the metal of silex; but its differences depend chiefly on the various proportions of carbon, which is greatest in the black, and least in the white, variety of iron. Berzelius, indeed, denies the presence of oxygen in cast iron, and says that its different kinds are produced by variable proportions of charcoal, manganese, and the metallic bases of magnesia and silex.† By the process of refining, the carbon and oxygen, it has been supposed, 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, the latter of which, even in very ductile iron, amounts, according to Berzelius, to about one half per cent. Hassenfratz has suggested that iron, which has been manufactured with wood charcoal, may probably contain protassium, and may owe its superiority to this circumstance; and Berzelius has rendered it probable that even the most ductile iron contains silicium.‡

If bar iron be long and slowly heated, in contact with charcoal, it loses oxygen and acquires carbon, and thus becomes *steel.* A small proportion only of carbon 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. The charcoal, which it contains, appears in the form of a black stain, on applying a drop of almost any weak acid to the surface of polished steel.

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 may be obtained by washing off the alkali of the nitre.

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* Ann. de Chim. et Phys. iii. 217.

† 40 Phil. Mag. p. 245.

‡ 78 Ann. de Chim. p. 233.

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, Sir H. Davy found that its characters remained wholly unaltered. Neither could any evidence of its containing oxygen be derived from the action of potassium.[*] But when exposed to the focus of a powerful lens in oxygen gas, he has lately observed that the gas became clouded during the process, and that there was a deposition of dew on the interior surface of the glass globe; a fact which indicates that plumbago, like charcoal, contains a small proportion of hydrogen.

Iron unites with various other metals. With potassium and sodium, it forms alloys more fusible and whiter than iron, and which effervesce when added to water. Stromeyer[†] has investigated the alloy of iron and silicium. It is formed by heating together iron, silex, and charcoal. The alloy is dissolved very slowly by acids, for it becomes covered with a coat of silex, which defends it from farther action, till it has been removed. Manganese forms a white and brittle alloy with iron. Iron, also, forms an alloy with tin; and iron plates, previously cleaned by a dilute acid, may be covered with tin by dipping them into that metal when melted.

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 be free from 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.

Other processes, for obtaining and purifying nickel, are described by Richter in the 12th volume of Nicholson's Journal; by Robiquet in the 69th, and by Tupputi in the 78th, volumes of the Annales de Chimie. The last-mentioned memoir contains an elaborate investigation of the properties and combinations of nickel.

Pure nickel has the following characters:

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[*] Philosophical Transactions, 1809.

[†] 81 Ann. de Chim.

1. Its colour is white, and intermediate between those of silver and tin. It admits of being finely polished, and has then a lustre between those of steel and platinum. When ignited, its colour changes to that of antique bronze, which is increased every time the metal is heated.

2. It is perfectly malleable, and may be forged when hot into bars, and hammered into plates when cold. At 54½° Fahrenheit, Tourte found its specific gravity 8.402, and, after being thoroughly hammered, 8.932. It is ductile, and may be drawn into very fine wire. It cannot easily be soldered, on account of the oxide which forms on its surface when heated. Its power of conducting heat is superior to that either of copper or zinc. Its magnetic property is very remarkable, and is retained when it is alloyed with a little arsenic, and, as Lampadius has shown,[*] with other metals. In difficult fusibility by heat, it appears to equal manganese.

3. Nickel appears to be susceptible of two different states of oxidation. By long exposure to a red heat, with free access of air, it is converted into a dark brown oxide, which is still magnetic. In oxygen gas, it burns vividly, and throws out sparks. When precipitated from its solutions by alkalies, 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. Tupputi, from 100 grains of nickel dissolved in nitric acid, precipitated by a fixed alkali, and calcined, obtained 127 grains of an ash-grey powder, which is to be considered as the *protoxide*. Hence it is composed of

Nickel	78.8
Oxygen	21.2
	100.

Thenard describes a black peroxide of nickel, obtained by passing a current of chlorine gas, through water, in which the hydrate is suspended. Its precise composition is unknown. In a sufficiently high temperature, its oxides are reducible without addition; nor is it more tarnished by a strong heat than gold, silver, or platinum. It ranks, therefore, among the noble or perfect metals.

4. 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. The fixed alkalies occasion a bulky greenish white precipitate, which is a hydrate or hydro-oxide of nickel, composed of 76 per cent. of the protoxide and 24 water.

5. When pure ammonia is added to nitrate of nickel, a precipitate is formed, resembling that which is separated by ammonia from a so-

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[*] Thomson's Annals, v. 62.

lution 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 retain its blue colour, the presence of copper is indicated.* This precipitate, which is a hydrate, is soluble by an excess of ammonia; and by this property the oxide of nickel may be separated, in analyses, from those of almost all other metals.

6. Nickel, when heated in chlorine, affords an olive-coloured compound; and the liquid muriate, when evaporated and strongly heated, gives brilliant white scales, which consist of nickel and chlorine. From analogy, the first should contain the largest proportion of chlorine; but the analysis of these compounds has not yet been accurately effected.

7. 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. Nickel may, however, be combined directly with sulphur by fusion, and forms a grey compound with a metallic lustre. It contains, according to Mr. E. Davy's experiments, 34 per cent. of sulphur; and the super-sulphuret, which may be formed by heating the protoxide with sulphur, is stated, by the same chemist, to contain 43.5 per cent. of sulphur.

9. 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.

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

11. The solutions of nickel do not deposit the metal either on polished iron or zinc.† 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 of nickel is greatly improved by the action of zinc.

12. 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 analyzed, however remote from each other the parts of the world in which they have fallen. In these, it forms from 1½ to 17 per cent. of their weight. It enters, also, into the composition of the large masses of native iron discovered in Siberia and in South America.

To detect, in a general way, the presence of nickel in iron, Dr. Wollaston recommends that a small quantity (which need not exceed 1-100th of a grain) should be filled from the specimen; dissolved in a drop of nitric acid; and evaporated to dryness. A drop or two of pure liquid ammonia, added to the dry mass and gently warmed, dissolves any nickel that may be present. The transparent part of the

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* See Richter in Nicholson's Journal, xii.

† See Klaproth's Analytical Essays, i. 433.

fluid is then to be led, by the end of a glass rod, to a small distance from the precipitated oxide of iron; and the addition of a drop of triple prussiate of potash detects the presence of nickel by the appearance of a milky cloud, which is not discernible in the solution of a similar quantity of common wrought iron treated in the same manner. The method of ascertaining the quantity of nickel in its alloy with iron, employed by the same philosopher, will be described in the chapter on mineral analysis.

SECTION X.

Tin.

The properties of tin must be examined in the state of grain-tin or block-tin; what is commonly known by the name of tin, being nothing more than iron plates with a thin covering of this metal. Several varieties are met with in commerce, for the discrimination of which, and the means of judging of their purity, Vauquelin has given useful instructions in the 77th volume of the Annales de Chimie. Cornish tin has been shown by Dr. Thomson to contain only a very minute proportion of foreign metals, never exceeding, and for the most part much less than 1-500th part, which is chiefly copper derived from the ore.*

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 leaves, 1-1000th of an inch thick.

I. Tin melts on the application of a moderate heat, equal to 442° Fahrenheit, by a long continuance 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. It may be procured, also, by calcining, in a close vessel, the precipitate from fresh made muriate of tin by carbonate of potash.

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 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. It may, also, be procured, as Berzelius found, by distilling powdered tin with red oxide of mercury.

The oxides of tin have been investigated by Gay Lussac and Berzelius, and their results differ so little, that either of them may be presumed to be correct. Gay Lussac states the composition of the protoxide to be

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* Thomson's Annals x. 166.

Tin	88.10	100.
Oxygen	11.90	13.6
	100.	

And that of the peroxide, in which he agrees with Klaproth,

Tin	79	100.
Oxygen	21	27.2
	100*	

Besides these two oxides, Berzelius suspects the existence of an intermediate one, which is formed when tin is acted on by nitro-muriatic acid; and which enters into the composition of deuto-chloride of tin.† It has a yellow colour, and, from theory, should consist of 100 metal + 20.4 oxygen; but he does not appear fully to have satisfied himself on the subject; and its existence is thought by Gay Lussac to be extremely questionable.

The oxides of tin have, in a certain degree, the properties of acids, so as to render it doubtful whether they should not be arranged in that class of compounds. But their affinities for bases are so extremely feeble, that it seems adviseable, on the whole, to retain them in the class of oxides.

The precipitates from solutions of tin by alkalies are *hydrates*, and have a white colour. They are soluble in an excess of fixed alkali; but the oxide is precipitated by the weakest acid, even the carbonic. The hydrates of tin are, also, decomposed by the action of boiling water. Dr. Thomson has described two hydrates, the one composed of 100 peroxide and 24 water, the other of 100 peroxide and 48 water.‡

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 deposits, 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

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* Ann. de Chim. et Phys. i. 43; and v. 151.

† 87 Ann. de Chim. 50.

‡ Annals of Phil. x. 149.

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 deposits 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 consists of protoxide of copper;* 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 oxidation, 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 platinum, 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 chlorine, by first forming it into amalgam with mercury, triturating this with an equal weight of corrosive sublimate, 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 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 *oxymuriate of tin* (or, according to the theory of chlorine, a *perchlorine of tin*), perfectly free from water, and having a 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. It may be formed at once, by heating tin in chlorine gas; and it consists, according to Dr. Davy, who calls it *stannanea*, of

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* Thomson's Annals, x. 71.

† On the preparation of muriate of tin, see Berard, Annales de Chimie, lxviii. 78; or Nicholson's Journal, xxvi.; and Chaudet, Ann. de Chim. et Phys. iii. 376.

Perchloride	Tin	45	100
	Chlorine	55	122
		100	

Another compound of tin and chlorine, called by the same chemist *stannane*, but more properly named *protochloride of tin*, may be obtained by heating together an amalgam of tin and calomel. It dissolves in water, and forms a solution, similar to the muriate of the protoxide, which rapidly absorbs oxygen from the air, and deposits peroxide of tin. It is composed of 55 tin and 33.5 chlorine, or

Proto-chloride	Tin	62	100
	Chlorine	38	62
		100	

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 deposits an insoluble oxide.

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

X. Tin unites with sulphur, but requires, for its combination, so high a temperature, that at the moment of union there is too small a quantity of sulphur present, to saturate the tin, and a mechanical mixture results of tin and sulphuret of tin. The only method of obtaining the saturated sulphuret, is to melt the *aurum musivum*, which will presently be described, in close vessels. The *proto-sulphuret* is of a bluish colour and lamellated structure. It is composed, according to Dr. John Davy and Berzelius, of

Tin	78.6	100.
Sulphur	21.4	27.234
	100.	127.234

The second sulphuret, or *per-sulphuret* of tin, (*aurum musivum,*) is formed by heating sulphur with peroxide of tin. It is of a beautiful gold colour, and flaky in its structure. Proust was of opinion that it is a sulphuretted oxide; but Dr. Davy and Berzelius have shown that the tin is in a metallic state. According to the former, it consists of

Tin	64.5	100.
Sulphur	35.5	54.5
	100.	154.5

Berzelius, by redistilling per-sulphuret of tin with sulphur, obtained a compound of a greyish colour and metallic lustre, which he found to be composed of 100 tin and 40.851 sulphur, or exactly intermediate between the two which have been already described. It is probable, however, that it was merely a mixture of the two sulphurets, and not a distinct compound.

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*. Tin enters, also, into the composition of *bell-metal and bronze;* and one of the most useful applications of it is to the tinning of iron plates, which is effected by dipping the plates into melted tin. The process, however, requires several preliminary steps, which are described in Watson's Chemical Essays, vol. ix., and in Mr. Parkes's Chemical Catechism.

SECTION XI.

Lead.

To obtain lead in a state of purity, Berzelius dissolved it in nitric acid, and crystallized the salt several times, till the mother liquor, on adding carbonate of ammonia, gave no traces of copper. The pure nitrate of lead, mixed with charcoal, was strongly heated in a Hessian crucible; and the lead, which separated, was kept some time in a state of fusion, in order to free it entirely from charcoal. The lead, thus obtained, when redissolved in nitric acid, gave no trace of any other metal.

Lead has a bluish 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.

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* On the alloys of tin, a memoir of M. Dussausoy may be consulted in the 5th vol. of Ann. de Chim. et Phys.; and Mr. Chaudet's paper in the same and in the 7th volumes.

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 three distinct oxides. 1. The *yellow oxide* may be obtained by decomposing nitrate of lead with carbonate of soda, and igniting the precipitate, or by heating the nitrate to redness in a close vessel. This oxide is tasteless, insoluble in water, but soluble in potash and in acids. When heated, it forms a yellow semi-transparent glass. Another form of the yellow oxide is that which is known in commerce by the name of *massicot*.

The yellow or *protoxide* of lead has been investigated by Proust, Thomson, and Berzelius; and its composition, as determined by the last mentioned chemist, is

Lead	92.85	100.	1298.7
Oxygen	7.15	7.7	1000.
	100.		

2. The second, or *deutoxide* of lead, may be obtained by exposing the protoxide of lead, or the metal itself, to heat, with a large surface and a free access of air, for some time, till, at length, it is converted into a red oxide, known in commerce by the names of *minium* or *red lead*. This, however, is an impure substance, containing sulphate of lead, muriate of lead with excess of base, oxide of copper, silex, and a portion of the yellow oxide. This, Berzelius found, may be removed by acetic acid, which does not act on the red oxide. Making allowance for the other impurities, he determined the composition of red oxide of lead, which may be considered as the deutoxide, to be

Lead	90	100.
Oxygen	10	11.08
	100	

When minium is digested with nitric acid, one part of it is reduced to the state of yellow oxide, and is dissolved by the acid; and the remainder is a brown oxide, contaminated (if pure minium has been used) with the substances which have been mentioned. This oxide may be procured, also, by passing a current of oxymuriatic acid gas through water, in which the red oxide is kept suspended, and by precipitating with caustic potash, and drying the oxide. It is of a flea or puce colour; very fine and light in its texture; and insoluble in nitric acid. When strongly heated, it gives out three or four per cent. of oxygen gas, and is converted into yellow oxide. It consists, according to Berzelius, of

Lead	86.51	100.
Oxygen	13.49	15.6
	100.	115.6

On comparing the quantities of oxygen united with 100 parts of lead, in these three oxides, we shall find that the numbers 7.7, 11.08, and 15.6, are very nearly in the proportion of 1, 1½, and 2. If, therefore, we multiply these last numbers by 2, we shall have the oxygen, in the three oxides of lead, represented by 2, 3, and 4; and this view of the subject would render it probable, that there exists an oxide of lead, with less oxygen than any at present known. I have, therefore, till this can be decided, retained the names of the three oxides which are derived from their colour, viz. the *yellow*, the *red*, and the *puce* oxides.

The yellow oxide of lead, when precipitated by pure alkalies from its compounds, forms a white *hydrate*, the composition of which is not exactly known.

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 quantity of lead required for silver of various degrees of fineness may be learned from a memoir of d'Arcet, in the first volume of Annales de Chim. et Physique.

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. Mere trituration of the peroxide in a mortar with a little sulphur, and the subsequent addition of a small bit of phosphorus, occasions a violent explosion.*

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 drunk.

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* Thomson's Annals, ix. 31.

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, which is stated by Berzelius as follows:—

Sulphuric acid	26.34	100
Yellow oxide	73.66	279
	100.	379

If the whole oxygen in the sulphate of lead be supposed to be divided into four parts, one of these, it is remarked, by Berzelius, is combined with the lead, and three with the sulphur. In the sulphite, one third of the oxygen is united with the lead, and two thirds with the sulphur.

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 7½ parts of boiling water. They contain no water of crystallization, and consist, according to Berzelius, of

Nitric acid	32.78	100.
Yellow oxide	67.22	209.5
	100.	309.5

Chevreul considers this salt as a super-nitrate,[*] and describes a scaly salt, which is the neutral nitrate, consisting of

Nitric acid	19.86	100
Yellow oxide	80.14	403
	100.	503

By boiling 4 parts of the super-nitrate, and 6 of lead, with 350 parts of water, for 14 hours, Chevreul obtained a liquid, which yielded

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[*] On the presence of lead in water, consult Dr. Lambe's "Researches respecting Spring Water," (8vo. London, Johnson,) and also Guyton, 26 Nich. Journ. 102.

[†] 1 Thomson's Annals, 101.

two sorts of crystals; the one, in the form of plates, a *nitrite;* and the other, in the shape of needles, a *sub-nitrite.* The nitrite was little soluble in cold water, and boiling water dissolved only about a tenth of its weight. It was decomposed by all the acids that were tried. Its constituents are

Nitrous acid	18.15	100
Yellow oxide	81.85	450
	100.	

The sub-nitrite crystallized in needles, of which 100 parts of boiling water dissolved about three parts, and retained one, when cooled down to 73° Fahrenheit. It consisted of

Nitrous acid	9.9	100
Yellow oxide	90.1	910
	100.	

V. When the nitrate, or any other soluble salt of lead, is added to a solution of common salt, a precipitate takes place of muriate of lead. The same compound may, also, be obtained by heating lead in chlorine gas, or by treating the oxides of lead with muriatic acid. When dry, the compound is a dull semi-transparent substance, fusible at a heat below redness, and volatile at an intense heat. It has a sweet taste, and is soluble in 22 parts of cold water. It has successively received the names of *horn lead, muriate of lead,* and *plumbane;* Berzelius states its composition to be

Muriatic acid	19.64	100.
Yellow oxide	80.36	409.06
	100.	

But according to Sir H. Davy, it is a compound of chlorine with metallic lead, or *chloride of lead,* composed of

Chlorine	24.62	100
Lead	75.38	306
	100.	

When two parts of the red oxide of lead are mixed with one of muriate of soda, and the mixture is made into a paste with water, the common salt is decomposed, and a muriate, or probably a sub-muriate or *sub-chloride* of lead is formed, which, on fusion, affords the substance called *mineral* or *patent yellow.* The soda is disengaged; and attracts carbonic acid from the atmosphere, but not enough to convert it into a carbonate. In the large way, it is found necessary to supply carbonic acid to the soda, thus prepared, by burning it with saw-dust.

VI. Carbonic acid may be brought to combine with protoxide of 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. According to Berzelius, it consists of

Carbonic acid	16.5
Oxide of lead	83.5
	100.

VII. 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, or more properly 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.

Acetate of lead consists, according to the experiments of Berzelius, of

Acid	26.97	100.
Yellow oxide	58.71	217.662
Water	14.32	
	100.	

By boiling in water, a solution of 100 parts of acetate and 150 of finely pulverized litharge, the acetate passes to the state of sub-acetate. The taste of this salt is less sweet; it is less soluble in water; and crystallizes in plates. It is composed, according to Berzelius, of

Acid	13.23	100
Yellow oxide	86.77	656
	100.	

The oxide in the sub-acetate is, therefore, so nearly three times that contained in the acetate, that we may consider the composition of these salts as furnishing an additional example of the law of simple multiples.

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.

VIII. The yellow oxide of lead unites with phosphoric acid, either directly or by mixing the solutions of a neutral alkaline phosphate and of nitrate or acetate of lead. The compound is insoluble, and is composed, according to Berzelius, of

Phosphoric acid	20.8	100.	26.2
Yellow oxide	79.2	380.5	100.
	100.	480.5	126.2

IX. Lead unites in its metallic state with sulphur; and affords a compound of a blue colour with considerable brilliancy called *galena*. This compound may, also, be formed artificially. It is remarked by Berzelius that the sulphur and lead, which it contains, are in such proportions, that when both are combined with oxygen, and converted, the one into sulphuric acid, and the other into yellow oxide of lead, the acid and oxide exactly saturate each other. These proportions he found to be

Sulphur	13.36	15.42	100.
Lead	86.64	100.	643.5
	100.00	115.42	743.5

SECTION XII.

Zinc.

THE zinc of commerce, known by the name of *speltre*, is never pure, but contains lead and sulphur. To purify it, zinc must be dissolved in diluted sulphuric acid; a plate of zinc is then to be immersed in the solution, to precipitate other metals, which it may contain; the solution must be decomposed by sub-carbonate of potash: and the precipitate ignited with charcoal powder.

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 beaten into leaves or drawn into wire.

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

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

II. By exposure to the air, at a low temperature, it slowly acquires a coating of grey oxide; but when kept in a degree of heat, barely sufficient for its fusion, zinc becomes covered with a grey oxide. If 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, containing some carbonate, 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 found it to consist of 80 parts of zinc and 20 oxygen. Gay Lussac* and Berzelius† have since investigated it, and agree in considering it as composed of

Zinc	80.39	100.
Oxygen	19.61	24.4
	100.	124.4

Zinc decomposes water very slowly at common temperatures, but with great rapidity, if the vapour of water be brought into contact with it when ignited. In whatever way it is oxidized, we obtain the compound already described, which is the only known oxide of zinc.‡

III. Zinc readily dissolves in diluted sulphuric acid, with the exception of a small quantity of black powder, which Vogel found to be composed of charcoal, iron, and sulphate of lead. The acid, during its action on this metal, evolves hydrogen gas; and the gas, when obtained, besides other impurities, 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 platinum 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 hydrozincic 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, when evaporated to a due degree of density, shoots into regular crystals. This salt is soluble in 2½ parts of water; and its solution is not precipitated by any other metal. Its composition is stated by Berzelius and Wollaston as follows:

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* 80 Ann. de Chim. 170. † 81 Ditto.

‡ Vogel in Thomson's Annals, vii. 33.

Acid	39.96	27.3
Base	32.69	28.4
Water	36.45	44.3
	100.[*]	100.[†]

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 birdlime.

Only one compound of zinc and chlorine is known. It may be formed by burning the metal in chlorine gas, or by distilling zinc filings with corrosive sublimate. It fuses at a heat a little above 212°; is volatile at a temperature below redness; and is identical with the compound, obtained by evaporating muriate of zinc. It consists, according to Dr. John Davy, as nearly as possible, of equal weights of metal and chlorine, or of

Zinc	49.5	100
Chlorine	50.5	102
	100.	

VI. Acetate of zinc may be formed either by directly dissolving the metal or 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. Mr. E. Davy, however, by passing the vapour of sulphur over melted zinc, obtained a white crystalline substance, resembling the natural compound of zinc and sulphur, called *phosphorescent blende*. The native sulphuret has been analyzed by Dr. Thomson, and found to consist of

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[*] Berzelius.

[†] Wollaston.

Zinc	67.19	100.	214.40
Sulphur	32.81	48.84	100.
	100.	148.84	314.40

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. It has been lately proposed to apply zinc to the purpose of culinary vessels, pipes for conveying water, sheathing for ships, &c.; but it is rendered unfit for the first, by the facility with which the weakest acids act upon it; and for the rest by its considerable, though slow oxidation when exposed to air and moisture.

SECOND CLASS.

METALS THAT ARE BRITTLE AND EASILY FUSED.

SECTION XIII.

Bismuth.

Bismuth has a reddish 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 acquainted; and consists, according to the experiments of Lagerhjelm,[*] of

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[*] 4 Thomson's Annals, 357.

Bismuth	89.863	100.
Oxygen	10.137	11.28
	100.	

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. The sulphate, on the same authority, is stated to consist of

Oxide of bismuth	66.353	100.
——— sulphuric acid	33.647	50.71
	100.	

Besides the neutral sulphate, Berzelius describes a sub-sulphate of

Oxide of bismuth	85.5	100
——— sulphuric acid	14.5	17
	100.	

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 hydrated oxide of bismuth with a small proportion of nitric acid. This pigment is liable to be turned black by sulphuretted hydrogen, and by the vapours of putrefying 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. The same compound is obtained by introducing finely divided bismuth into chlorine gas, when the metal takes fire, and burns with a pale blue light. It is the only known combination of bismuth and chlorine, and was found, by Dr. Davy, to contain 66.4 per cent. of the metal, and 33.6 of chlorine.

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 combines with sulphur, and forms a bluish grey sulphuret, having a metallic lustre. Lagerhjelm has analyzed it, and found it to consist of

Bismuth	81.619	100.
Sulphur	18.381	22.52
	100.	

VIII. 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 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, as stated by Proust, 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 supertartrate 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 a hammer. Or two parts of the sulphuret may be fused in a covered crucible with one of iron filings, and to these, when in fusion, half a part of nitre may be added. The sulphur quits the antimony, and combines with the iron.

In order to obtain antimony in a state of complete purity, the metal, resulting from this operation, must be dissolved in nitro-muriatic acid, and the solution must be poured into water. A white powder will precipitate, which must be dried, mixed with twice its weight of crude tartar, and fused in a crucible, when the pure metal will be produced.

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 heat of about 810° Fahrenheit; 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 antimony.* The vapour of water, brought into contact with ignited antimony, is decomposed with so much rapidity, as to produce a series of detonations.

V. 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 opaque on cooling. It is composed of

Antimony	81.5	100.
Oxygen	18.5	22.7
	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

Antimony	77	100
Oxygen	23	30
	100	

The oxides of antimony have been investigated by Berzelius,* who describes four degrees of oxidation in that metal. The first, or *sub-oxide*, is obtained by the long exposure of antimony to a humid atmosphere, or by making that metal the positive conductor in a Galvanic arrangement, pure water being employed to complete the circuit. To procure the sub-oxides, the antimony must be reduced to powder, and placed under water in contact with a platinum wire, connected with the positive end of the pile. Oxygen gas is disengaged from the point of contact, and the antimony is covered with a bluish grey flocculent powder, which is lighter than the metal, and may be separated by washing with water. It is produced so sparingly, that enough could not be obtained for analysis, and its composition was, therefore, deduced by calculation.

This second oxide (called by Berzelius the *oxidule*) may be obtained from muriate of antimony by an alkali. When the precipitate, which at first is a hydrate, is dried and heated, the oxide assumes a dull white colour, verging on grey. In a red heat, it fuses into a yellowish fluid, which, on cooling, becomes an almost white mass, crystallized something like asbestus.

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* 86 Ann. de Chim. 225.

The *third, or white oxide,* was formed by dissolving antimony in nitric acid, and evaporating and igniting the product; or by dissolving in nitro-muriatic acid, decomposing by water, washing the precipitate, and calcining it in a platinum crucible. Its colour, when properly prepared, is perfect or snow white.

The *fourth,* or yellow oxide, was obtained by Berzelius in the following manner: Powdered metallic antimony was fused, during an hour, in a silver crucible, with six times its weight of nitre; and the fused mass was washed, first with cold and then with boiling water. The liquid was evaporated to dryness, and digested many hours with nitric acid. The white powder, insoluble in nitric acid, was gently heated in a small platinum crucible, and assumed a fine lemon yellow colour. A similar product was obtained by mixing powdered antimony with pure oxide of mercury. An olive substance was produced, which, by long exposure to heat, assumed a straw yellow colour. This oxide, by a strong heat, loses about 6½ per cent. of oxygen, and is changed into the white oxide.

The composition of these four oxides is thus stated by Berzelius:

	Metal.	Oxygen.	Metal.	Oxygen.
1. Sub-oxide	96.826	3.174	100	4.65
2. Oxidule	84.317	15.683	100	18.60
3. White oxide	78. 19	21. 81	100	24. 8
4. Yellow oxide	72. 85	27. 15	100	37.20

It is probable, from the law of definite proportions, that the first or sub-oxide will prove to be a mechanical mixture of metallic antimony with the second or oxidule, which, in that case, will be the true *protoxide.* If this be established, it will afford another example of the general principle, that in protoxides, the oxygen is equal to half the sulphur of the sulphuret.

The white and yellow compounds of oxygen and antimony ought, indeed, to be arranged among acids, rather than among oxides; for each of them combines with salifiable bases, and affords a class of salts. The first may be called the *antimonious* acid, and its compounds *antimonites;* the second the *antimonic* acid, and the salts which it composes *antimoniates.* These names appear to me preferable to those which have been derived, by Berzelius, from the Latin appellation *stibium,* viz. *stibious,* and *stibic acids.* For a detail of the properties of these saline combinations, I refer to the memoir already quoted, and to the 5th volume of Ann. de Chim. et Phys.

VI. Antimony combines with sulphur, and forms an artificial sulphuret, exactly resembling the native compound, which last may be employed, on account of its cheapness, for exhibiting the properties of sulphuret of antimony. The proportions of its ingredients, as stated by Berzelius, differ from those assigned by Proust, *viz.*

Antimony	72.86	100.	270
Sulphur	27.14	37.25	100
	100.		

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 mostly converted into a grey oxide. This, being melted in a strong heat, acquires a reddish colour, and runs into a glassy substance, transparent at its edges, and termed *glass of antimony.* It consists of eight parts of protoxide and one of sulphuret, with ten *per cent.* of silex. The same quantity of oxide and two of sulphuret give an opaque compound, of a red colour inclining to yellow; and called *crocus metallorum.* With eight parts of oxide and four of sulphur, we obtain an opaque mass of a dark red colour, called *liver of antimony.* In all these compounds, the oxide is at its minimum of oxidation; for the peroxide 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 native sulphuret with pure potash. The solution, on cooling, deposits an hydro-sulphuretted oxide, in which the oxide prevails, called *kermes mineral.* The addition of a dilute acid to the cold solution, precipitates a compound, having the same ingredients, but a larger proportion of sulphur, and called *golden sulphur of antimony.*

3. When the sulphuret of antimony is detonated with twice its weight, or upwards, of powdered nitre, the sulphur is oxygenated by the oxygen of the nitric acid; sulphate of potash is formed, and an oxide of antimony is obtained, varying in its degree of oxidation, with the proportion 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 oxygen, and acquires somewhat of the character of an acid; since it forms, with potash, a crystallizable compound.

VII. Antimony is dissolved by most of the acids. Sulphuric acid is decomposed by it; sulphurous acid being dissengaged, and an oxide formed, of which a small proportion only is dissolved by the remaining acid, constituting a sub-sulphate. Nitric acid dissolves this metal with great vehemence; but muriatic acid acts on it very feebly, even by long digestion. The most convenient solvent is the nitro-muriatic acid, which, with the aid of heat, dissolves it either in its reguline state, or as existing in the native sulphuret. With oxy-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 oxy-muriatic acid, and by subsequent distillation; or by distilling the powdered metal with twice its weight of corrosive muriate of mercury; or by the action of nitro-muriatic acid on metallic antimony.* It may be formed, also, by the combustion of antimony in chlorine gas, with which, according to Dr. John Davy, it unites in the following proportion:

Antimony	66	100	150
Chlorine	44	67	100
	100		

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* Robiquet in Ann. de Chim. et Phys. iv. 165.

On pouring this compound, which may be termed *chloride of antimony*, into water, a white hydrate, containing some muriatic acid, falls down, called *powder of algaroth*. This furnishes a delicate test of the presence of antimony in solutions effected by muriatic acid, and containing that metal in very small proportion, along with tin or others.

VIII. Antimony enters into combination with most of the metals. It destroys the ductility of gold, even when it composes only 1-2000th 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. It may be alloyed with tin, but if its proportion in the alloy exceeds one-fourth, the tin loses its ductility. Tin, also, by combination with more than one-twentieth of its weight of antimony, acquires the insolubility of the latter metal in muriatic acid.[*] In analyzing compounds of tin and antimony, it is necessary first to make an alloy, in which the antimony shall not exceed the above proportion of 1-20th part, for then concentrated muriatic acid, by digestion with this alloy, dissolves the tin, and leaves the antimony.

SECTION XV.

Tellurium.

I. TELLURIUM was discovered, by Klaproth,[†] 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, quicksilver, and selenium, is the most volatile of all metals. It is the lightest of the metals, the bases of the alkalies and earths excepted, 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 blowpipe, it inflames with a violence resembling detonation; exhibits a

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[*] Ann. de Chim. et Phys. iii. 380.

[†] Contributions, ii. 1.

vivid flame; and entirely flies off in a grey smoke, having a peculiarly nauseous smell. This smoke, when condensed, and examined in quantity, is found to be white with a tint of yellow. It is fusible by a strong heat, and volatile at a still higher temperature. It not only unites as a base with acids, but also itself possesses the character of an acid, and forms a class of salts, which may be called *tellurates*. It is composed, according to Klaproth, of

Tellurium	83	100.
Oxygen	17	20.5
	100	

Berzelius, however, determines the quantity of oxygen, absorbed by 100 of tellurium, when changed into oxide, to be 27.83.

3. Tellurium 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. Chlorine unites with tellurium, and forms a white semi-transparent compound, which is decomposed when added to water. It consists, according to Sir H. Davy, of 100 tellurium united with 90.5 chlorine. From its solutions it is precipitated in a metallic form, by iron, zinc, tin, and even by muriate of tin. Carbonated and pure alkalies precipitate the telluric oxide united with water, in the form of a white hydrate; 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 possesses in common with gold, platinum, iridium, osmium, rhodium, and antimony.

Tellurium forms two distinct compounds with hydrogen, the one of which is solid and the other gaseous—1st. By making tellurium the negative surface in water, in the Galvanic circuit, a brown powder is formed, which is a solid *hydruret of tellurium*.

2dly. By acting with dilute sulphuric acid, upon the alloy of tellurium and potassium (which may be obtained by heating a mixture of solid hydrat of potash, tellurium, and charcoal,) we obtain a peculiar gas. This gas has a smell resembling that of sulphuretted hydrogen. It is absorbed by water, and a claret-coloured solution results, which by exposure to the air, becomes brown, and deposits tellurium. After being washed with a small quantity of water, it does not affect vegetable blue colours. It burns with a bluish flame, depositing oxide of tellurium. It unites with alkalies; precipitates most metallic solutions; and is instantly decomposed by chlorine gas. It may be called *telluretted hydrogen gas*. According to Berzelius, it is constituted of 100 parts of tellurium with a little less than two parts of hydrogen.

SECTION XVI.

Selenium.

In the chambers for manufacturing sulphuric acid, from the sulphur which is procured at Fahlun in Sweden, a reddish mass is deposited, which is principally sulphur. This substance, in burning, gave out an odour, which induced Berzelius to suspect that it contained tellurium, but on a minute examination he discovered, instead of that metal, one with entirely new properties, to which he has given the name of *selenium*. The process, by which it was extracted, is not described, and on that account, as well as of the scarcity of the substance which affords it, I shall give only a very general view of its properties.

Selenium has a grey colour, and a very brilliant metallic lustre, and possesses a small but scarcely perceptible degree of transparency. It softens at 212° Faht., and completely fuses at a few degrees higher. While cooling, it has a considerable degree of ductility, and may be kneaded between the fingers, and drawn out into fine threads, which have a strong metallic lustre. When slowly cooled, it assumes a granulated fracture, and is extremely like a piece of cobalt. At a temperature nearly equal to that of boiling mercury, selenium enters into ebullition; and condenses, either into opaque metallic drops, or, when a retort with a large neck is used, into flowers of a fine cinnabar colour.

When heated before the blow-pipe, it tinges the flame of a fine azure blue, and exhales so strong a smell of horse-radish, that a fragment, not exceeding 1-50th of a grain, is sufficient to fill the air of a large apartment.

Selenium unites with the different metals, and the union is, in many cases, accompanied with ignition. The seleuret of potassium has a metallic lustre, and a greyish white colour. Its solution in water has the colour of strong ale, and a smell resembling that of sulphuret of potash. Acids disengage, from this solution, a gas, which appears to be a solution of selenium in hydrogen gas. A small bubble of this gas, not exceeding a pea in size, when drawn into the nostrils, excited inflammation of their membrane, and symptoms of catarrh, which did not subside for several days.

Selenium unites with the fixed alkalies, both in the moist way and by fusion; and the compounds have a cinnabar-red colour. It dissolves in fixed oils, and the solutions are red, but have not the hepatic smell of solutions of sulphur.

Selenium dissolves in nitric acid with the assistance of heat; and the resulting compound, after evaporation to dryness, may be easily sublimed into crystalline needles, which are often a foot in length. This sublimate is soluble in water and in alcohol, and has the taste and all the properties of an acid. It may, therefore, be called *selenic acid*, and its compounds *seleniates*. The alkaline seleniates are not readily crystallizable; and they attract moisture from the atmosphere.

If a little muriatic acid be added to the solution of a seleniate in water, and a plate of zinc be then introduced, the selenium is precipitated in a metallic state. Selenic acid is decomposed by sulphuretted hydrogen, and an orange-coloured precipitate is obtained, which becomes red when dried. When a slip of paper, moistened with solution of selenic acid, is exposed to a current of sulphurous acid gas, the selenium is revived in the form of a film resembling gold.

It has been doubted whether selenium can, with propriety, be classed among the metals. But though it scarcely conducts caloric, and is a non-conductor of electricity, Berzelius is still of opinion, from a review of its other properties, that it is fully entitled to be considered as a metal; and that its proper place is among the acidifiable metals, near to arsenic.*

SECTION XVII.

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; keeping the upper one as cool as possible. 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. Metallic arsenic 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.

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

IV. 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 placed 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.

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* Thomson's Annals, xi. 291, 374, 447, xii. 13; and Ann. de Chim. et Phys. vii. 199.

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

VI. Arsenic, by exposure to the air, is tarnished, and becomes converted into a bulky blackish powder. In three months, Berzelius found that 100 parts acquired an increase of 8.475; and he is disposed to consider the product as an oxidule; but it is probably nothing more than a mixture of arsenic and arsenious acid, into both which, indeed, it is resolved by heat. Only two combinations of arsenic and oxygen have hitherto been clearly ascertained; and both are possessed of acid properties.

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. Other statements have been given considerably differing from these; and Klaproth was, therefore, induced to examine its degree of solubility with great attention. A thousand grains of cold water, left in contact with the white oxide during 24 hours, and frequently agitated, dissolved only 2½ grains. But 1000 grains of boiling water took up 77¾ grains; and, after being left three days to cool, and to deposit the crystals which separated, still retained in solution 30 grains. Bucholz has since published results, which agree, very nearly, with those of Klaproth. But the most elaborate experiments are those of Fischer of Breslau. According to these, white oxide of arsenic is insoluble in water, and when acted upon by water, one portion of the oxide acquires oxygen from another, and becoming acidified, is rendered soluble. This is the reason why the undissolved portion loses its colour, and becomes of a dirty yellow. Of boiling water, 12.3 parts dissolve one of arsenic; but at the common temperature of the atmosphere, 66½ parts of water take up only one part.[*]

The solution of the white oxide of arsenic has an acrid taste, and reddens vegetable blue colours. When slowly evaporated, the oxide crystallizes in regular tetrahedrons. The oxide 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.

3. The composition of the white oxide of arsenic, or *arsenous acid*, has been investigated by several chemists, with the following results. It consists,

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[*] Thomson's Annals, vii. 33.

	Arsenic.	Oxygen.	Arsenic.	Oxygen.
According to Proust, of	75.2	24.8	100	32.979
——— Thenard, of	——	——	100	34.694
——— Berzelius, of	74.48	25.52	100	34.263[*]
——— Do. corrected	69.63	30.37	100	43.616
——— Thomson, of	——	——	100	34.930

It has been justly observed, however, by Dr. Thomson,[†] that the result, which Berzelius considers as the most correct, is probably the least so; not only on account of its want of accordance with other determinations, but on account of the complicated process, by which it was obtained. On the whole, it appears probable, that 100 parts of arsenic, to become the white oxide, combine with between 34 and 35 parts of oxygen.

4. Oxide of arsenic combines with the pure alkalies 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 the respective bases and a sufficient quantity of water; or by double decomposition. Thus arsenite of lead may be prepared, by mixing the solutions of nitrate of lead and arsenite of potash; and the fine green pigment called *Scheele's green*, by mixing the solutions of arsenite of potash and sulphate of copper.

5. 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. Orpiment contains three parts of sulphur and four of arsenic; and realgar one part of sulphur and three of arsenic. Hence realgar, by fusion with an additional quantity of sulphur, may be changed into orpiment; and the latter, by an addition of arsenic becomes realgar. The opinion of Laugier, that both are sulphurets at the same degree, combined with different proportions of white arsenic, is combated by Berzelius, who could not extract any arsenious acid from orpiment.[‡]

6. 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 oxymuriatic acid, and the subsequent 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.

VII. 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 carbo-

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[*] Corrected by him afterwards to 31.77.

[†] Annals, iv. 171.

[‡] Ann. de Chim. et Phys. v. 179.

nates. When evaporated, it assumes the consistence of jelly, and does not crystallize. It is a most active poison. With alkalies, 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.

The statements of the composition of arsenic acid differ from each other not less than those of the white oxide. It is composed,

	Arsenic.	Oxygen.	Arsenic.	Oxygen.
According to Proust, of	65.4	34.6	100	52.905
——— Thenard, of	64.	36.	100	56.250
——— Berzelius, of	66.038	33.962	100	51.428*
——— Do. corrected	58.366	41.634	100	71.333
——— Thomson, of	——	——	100	52.4

In this case, also, Dr. Thomson prefers, and it appears to me with reason, the first determination of Berzelius, as more nearly approaching the truth than the second. Dr. Thomson's result was obtained by the direct acidification of metallic arsenic by nitric acid; and, though not coincident with the analysis by Thenard, yet it agrees with the number, obtained by assuming the proportions, given by that chemist, for the white oxide, and with his assertion that 100 parts of arsenous acid are changed into arsenic acid, by 16 parts of oxygen.

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. The greatest caution should be used to avoid its deleterious effects, which were fatal to the late M. Gehlen.†

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; but its specific gravity is variable, in consequence of the admixture of different proportions of hydrogen gas.

(*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 oxymuriatic 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.

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* Corrected afterwards to 52.96; Ann. de Chim. et Phys. v. 179.

† 95 Ann. de Chim. 110; and Ann. de Chim. et Phys. iii. 135.

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

(*i*) When 100 measures, in an experiment of Gay Lussac, were acted upon by heated tin, 140 measures of hydrogen were evolved. Hence three volumes of hydrogen are, in this gas, condensed into almost the space of two.

A solid compound of hydrogen and arsenic may be formed, by acting on water with an alloy of potassium and arsenic; and, of course, much less hydrogen gas is evolved, than the same weight of uncombined potassium would liberate from water. It is described, by Gay Lussac, as separating in chesnut brown coloured flocks. There appears, indeed, to be a strong affinity between hydrogen and arsenic; for Berzelius found that the recently prepared metal, when distilled along with oxide of tin, gave a drop or two of water.

THIRD CLASS.

BRITTLE AND DIFFICULTLY FUSED.

SECTION XVIII.

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. It has lately been found by Stromeyer in a meteoric stone from the Cape of Good Hope.*

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 to be 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.

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* Thomson's Annals, ix. 249.

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. It is generally described to be magnetic; but this property Mr. Chenevix imputes to its contamination with a small quantity of iron.

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, formed by long exposure to a strong heat, with access of air, is of a deep blue, approaching to black. This, from the experiments of Thenard, appears to be the *protoxide.* It may be obtained, also, by precipitating the nitrate of cobalt with potash. The precipitate, which at first is a bright blue hydrate, when dry becomes of so dark a blue as to appear 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 quantity of oxygen; and becomes olive green. Treated with muriatic acid, it gives oxymuriatic acid gas, and a red solution is obtained. This olive compound Sir H. Davy suspects to be a mixture of hydrate and oxide of cobalt, and not a peculiar oxide.

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 in muriatic acid, with a copious disengagement of oxymuriatic 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 alkalies, or of tinging vitrifiable mixtures blue.

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

Cobalt	83½	100.
Oxygen	16½	19.8
	100	119.8

And 100 of the *peroxide* of

Cobalt	75	100.
Oxygen	25	33.25
	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.

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* Philosophical Magazine, xxx. 340.

The oxides of cobalt require, however, farther investigation. Klaproth states that 100 parts of cobalt absorb 18 of oxygen, to be converted into protoxide. But the oxygen of the peroxide does not, either on this or on Proust's data, bear the proportion to the oxygen in the protoxide, which might be expected from the law of definite proportions. If the oxide, described by Klaproth, be really that which is composed of one atom of metal and one of oxygen, the atom of cobalt will weigh 41.5; but if it be, as Sir H. Davy supposes, a deutoxide, or compound of one atom of metal with two of oxygen, the atom of cobalt must weigh 83. On the first supposition, the peroxide should be constituted of 100 metal and 36 oxygen; and, on the second, of 100 metal and 25.8 oxygen; and as the former of these numbers corresponds most nearly with experiment, we may consider the protoxide as the first combination of cobalt and oxygen, and the atom of cobalt to be represented by 41.5.

III. 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 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.

IV. Oxide of cobalt is precipitated by carbonated alkalies 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.

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

VI. Cobalt may be brought to combine with sulphur and with phosphorus; but the compounds have no peculiarly interesting properties. The sulphuret is composed, according to Proust, of

Cobalt	71.5	100.
Sulphur	28.5	39.8
	100.	

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

This confirms the view, already given, of the atomic constitution of the protoxide; for the oxygen, which it contains, is not far from being equal to half the sulphur in the sulphuret.

VII. 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 XIX.

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 was found by Dr. John to be 8.013. It is very brittle, and even less fusible than iron, requiring a heat of 160° Wedgwood to melt it. It is not attracted by the magnet; except when 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 succession grey, violet, brown, and finally black.

There is a remarkable want of agreement in different statements of the composition of oxides of manganese, and even of the number of those oxides. Sir H. Davy admits only two, one of a dark olive colour, consisting of 21 oxygen to 79 metal; the other of a dark brown colour, containing almost 10 per cent. more of oxygen.* Dr. John, in a memoir published in the 2d and 3d volumes of Dr. Thomson's Annals, enumerates three oxides of manganese, the green, the brown, and the black. The *green* is formed by the action of metallic manganese on water, from which it takes oxygen, and disengages hydrogen gas, apparently holding some of the metal in solution. He finds it to be composed of

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* Elements of Chem. Phil. 369.

Manganese	87	100.
Oxygen	13	14.942
	100	

The *brown* oxide was formed by exposing the last mentioned one to the air, till it ceased to gain weight, and then drying it quickly. Its colour was pure deep brown, and it was composed of

Manganese	80	100
Oxygen	20	25
	100	

The third or *black* oxide was prepared by dissolving manganese in nitric acid, evaporating, and drying by a heat sufficient to expel the nitric acid, but not to decompose the oxide. It consisted of

Manganese	71.33	100.
Oxygen	28.67	40.19
	100.	

The brown oxide still continued to absorb oxygen, when exposed to the atmosphere; but the black, when ignited, gave oxygen gas.

Berzelius[*] admits the composition of the green oxide, as stated by Dr. John, with a slight alteration; but corrects the numbers indicating that of the second and third, and adds, also, two other oxides, the one with less oxygen, and the other with more than any of those which have been already cited. The first is obtained by exposing metallic manganese in a vessel loosely corked; but there can be little doubt, from its properties, that it is a mixture of the metal and the green oxide. The second, described by Dr. John, results from the action of water on metallic manganese; the third from the action of acids; and the fourth from calcining the nitrate. The fifth and last is the native oxide of manganese, which is become important from its use in preparing chlorine. By exposure to a strong heat, 100 parts of this oxide lose 11.3 of oxygen, and a red oxide remains.

Berzelius's Table of the Composition of Oxides of Manganese.

	Metal.	Oxygen.	Metal.	Oxygen.
1st oxide	93.435	6.565	100	7.0266
2d oxide (green)	87.68	12.32	100	14.0533
3d oxide (brown)	78.10	21.90	100	28.1077
4th oxide	70.50	29.50	100	42.16
5th oxide	64.00	36.00	100	56.215

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[*] 87 Ann. de Chim. 149.

The numbers in the last column, it may be observed, stand to each other in the proportion of 1, 2, 4, 6, 8. But if the first compound (as appears to me probable) be not a distinct oxide, the ratio will then be that of 1, 2, 3, 4. Gay Lussac, indeed, has expressed his conviction,[*] that the two first oxides do not exist; and that there are in reality only three; 1st, the *protoxide*, obtained by dissolving manganese in diluted sulphuric acid, and precipitating it by a pure alkali out of the contact of air; 2d, the *deutoxide*, which remains after calcining the *peroxide* or the greater part of the salts of *manganese;* and 3d, the *peroxide*, or native black oxide. And Berzelius himself is now disposed to give up the two first,[†] and on the authority of his own experiments, to admit three oxides of manganese, with quantities of oxygen corresponding to the three last in the above table; the protoxide being green, and the two others black. The red compound of 100 parts of manganese with 37.47 oxygen, not agreeing with the law of definite proportions, he considers as a mixture of the two first.[‡]

The oxides of manganese may be combined with most of the acids. When the green or protoxide is precipitated from its solution in an acid by a carbonated alkali, we obtain a snow-white compound, which is a carbonate of manganese. It is composed, according to Dr. John, of

Protoxide of manganese	55.84
Water	10.
Carbonic acid	34.16
	100.

Concentrated sulphuric acid has very little action on metallic manganese; but the dilute acid dissolves it with an extrication of hydrogen gas, which has a peculiar smell, resembling asafœtida, probably from its holding some of the metal in solution. The solution has a light rose colour, and gives crystals of the same colour.

The pure protoxide, and the carbonate, dissolve in the sulphuric acid in any state of concentration; and a solution is obtained, exactly resembling that which has been described. The first crystals, that shoot from the solution, are of a faint rose red colour. The last are white, and contain a great excess of acid. The red crystals are soluble in 2½ parts of water, at 55° Fahrenheit, and are insoluble in alcohol. The alkaline carbonates, prussiates, and phosphates, occasion a white precipitate from the solution, and are almost the only salts that decompose this sulphate. It is composed of

Protoxide of manganese	31.00
Sulphuric acid	33.66
Water	35.34
	100.

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[*] Ann. de Chim. et Phys. i. 39.

[†] Ibid. v. 150.

[‡] Ibid. vi. 204.

The peroxide is not acted upon by sulphuric acid, except when concentrated, or very little diluted: and it is precipitated again by water added in considerable quantity.

Nitric acid, when moderately concentrated, dissolves metallic manganese with an escape of nitrous gas. The solution is colourless; and by long continued evaporation, the acid is decomposed, and a black oxide is left. The green oxide and white carbonate also dissolve readily in nitric acid, and by particular management crystals may be obtained from the solutions. The crystals deliquiate by exposure to the air; and on the application of heat, melt, and are immediately decomposed. The black oxide does not dissolve in nitric acid, unless a little sugar is added, or some other similar substance.

The action of muriatic acid is most important on the black native oxide. According to the old theory, part of the acid acts on one portion of the oxide; and first reduces it to the state of protoxide, and then dissolves it; affording muriate of manganese. The oxygen, thus liberated, uniting with another portion of muriatic acid, composes oxy-muriatic acid. But, on the theory of chlorine, the hydrogen of the muriatic acid is attracted by the oxygen of the oxide, and the chlorine is merely set at liberty.

When the muriate of manganese is evaporated to dryness, and strongly heated, it forms brilliant scales, which, according to Dr. John Davy, are identical with the compound obtained by burning manganese in chlorine, and are composed of

Manganese	54	100
Chlorine	46	85
	100	

Muriate of manganese is a deliquescent salt; it is soluble in an equal weight of water, and soluble, also, in alcohol, by which means it may be separated from the sulphate. It may be obtained in large tabular crystals, quite transparent, and of a rose colour. If considered as a compound of muriatic acid and oxide of manganese, it may be stated to consist of

Protoxide of manganese	38.50
Muriatic acid	20.04
Water	41.46
	100.

Dr. John has investigated, also, several of the combinations of oxide of manganese with vegetable and metallic acids, the details of which are contained in his paper.

The black oxide of manganese has some properties, which render it the subject of amusing experiments.

1. It imparts to borate of soda, when melted with it, a violet colour. When this is effected by the blow-pipe, the colour may be de-

stroyed by the interior flame, and again reproduced by the exterior one, or by a small particle of nitre.[*]

2. When black oxide of manganese and nitre, both reduced to powder, 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. The same compound may be obtained by fusing together one part of the black oxide, and five or six of solid caustic potash. It 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 blue; more still to purple; and a still larger quantity to a beautiful deep purple.

3. 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. Hence this compound has been termed the *chameleon mineral.* This property is destroyed by a very small quantity of sulphuret of potash, and by other substances that attract oxygen.

The properties of this singular substance have been lately investigated by Chevreul.[†] To exclude the presence of iron, on which Scheele suspected its green colour to depend, he prepared it by fusing, in a platinum crucible, one part of pure oxide of manganese with eight of potash, prepared with alcohol. The colour of the solution was still green, and by the addition either of more water, or of carbonic acid or an alkaline carbonate, became successively blue, violet, indigo, purple, and red. The green solution, Chevreul supposes, is a combination of caustic potash with oxide of manganese; and the red, of potash, oxide of manganese, and carbonic acid. The intermediate colours result from the combination of these in different proportions, as may be proved by the direct mixture of a green with a red solution. The agency of water, even when carefully deprived of carbonic acid, in effecting the same change, shows, however, that the theory does not account for all the phenomena. This fact Chevreul explains by the action of water in diminishing the attraction between the potash and oxide of manganese, in which way he apprehends that carbonic acid produces its effect. The oxide, both in the green and red compounds, he asserts, is at the same degree of oxidation, a degree probably inferior to that of the native oxide.

Messrs. Chevillot and Edwards have ascertained that the colour of the chameleon mineral is owing to oxide of manganese, and not to any other metal; that the contact of oxygen gas with the fused materials is essential to its formation, during which oxygen is absorbed; and lastly that the chameleon compound is susceptible of assuming a regular crystallized form.[‡]

III. Manganese, in its metallic state, cannot be brought to combine

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[*] See Klaproth, vol. i. page 243. a.

[†] Ann. de Chim. et Phys. iv. 47.

[‡] Ibid, iv. 287.

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.

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

SECTION XX.

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, and in some meteoric stones. A compound of chromic acid with oxide of iron has, also, been discovered in France and in America,* and is a much more abundant product than the lead ore of Siberia.

1. 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. Its specific gravity is 5.9.

III. It is susceptible of three states of oxidizement.—The first oxide is green, the second brown, and a farther proportion of oxygen gives the chromic acid. The precise quantity of oxygen in these different compounds has not yet been ascertained.

IV. The nitric acid alone exerts any remarkable action on this metal. Repeated distillation, with this acid, changes chrome into chromic acid, combinable with alkalies. The chromates of alkalies precipitate the salts of lead, of a beautiful yellow colour; which is now procured in considerable quantity from the American chromate of iron, and is highly valuable in painting. Mercury is thrown down from its solutions by chromates of alkalies, of a cinnabar-red hue; silver, of a carmine-red; and all its metallic combinations are distinguished by peculiar brilliancy of colour. The emerald derives its co-

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* Thomson's Annals, v. 75.

lour from the *oxide* of chrome; and the spinelle ruby from the *acid*. This property of imparting colour has suggested its name.

The combinations of the chromic acid with different bases have been fully investigated, and described by Vauquelin, in the 70th volume of the *Annales de Chimie*, and by Dr. John, in the 4th volume of Thomson's Annals of Philosophy. It has, indeed, been lately asserted, that the chrome acid is not a simple combination of chromic and oxygen; but that it always contains a portion of the acid, by which it has been precipitated from its alkaline compounds; in other words, that no true chromic acid exists.*

SECTION XXI.

Molybdenum.

I. THE most common ore of molybdenum, 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 molybdenum. These two components may be separated, by repeated distillation with nitric acid. To the ore of molybdenum, 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 molybdenum 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 (*molybdic acid*) is a white heavy powder; which has an acid and metallic taste; has the specific gravity 3.4; is soluble in about 1000 parts of water; and forms salts with the alkalies 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 molybdenum 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 molybdenum. This may be metallized by exposure to an intense heat with oil or powdered charcoal.

II. Molybdenum 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 8.611.

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 compound has acid properties.

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* Thomson's Annals, vii. 36.

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

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

There appear to be only two well ascertained compounds of molybdenum and oxygen. The first is the molybdic acid already described. It is composed, according to Bucholz, of

Molybdenum	66.7	100
Oxygen	33.3	50
	100.	

Berzelius states the metal at 65.5, and the oxygen at 34.5 in 100 grains of molybdic acid.

When one part of powdered molybdenum, and two parts of molybdic acid, are triturated in boiling water; then filtered; and the solution evaporated at a temperature not exceeding 120° Fahrenheit, we obtain a fine blue powder, which is molybdous acid. This acid is more soluble in water than the molybdic, and its solution reddens vegetable blue colours. It is stated by Bucholz to consist of

Molybdenum	74.5	100
Oxygen	25.5	34
	100.	

It seems not improbable that there is an oxide, containing a smaller proportion of oxygen than the molybdous acid; and that this acid is constituted of two atoms of oxygen to one of metal. On this supposition the atom of molybdenum must weigh about 44; and, in molybdous acid, it must be combined with two atoms of oxygen, weighing 15; and in molybdic acid with three atoms, weighing 22.5. The oxide, consisting of one atom of metal 44, and one atom of oxygen 7.5, remains to be investigated.

The molybdous and molybdic acids unite with salifiable bases, and form distinct classes of salts. The latter acid is changed into the former by some of those metals, that powerfully attract oxygen. Thus a solution of molybdic acid, in which a small rod of tin or zinc is immersed, becomes blue, in consequence of the partial disoxygenation of the acid; and on the same principle recent muriate of tin throws down, from molybdate of potash, a fine blue precipitate. The molybdic acid decomposes the nitrates of silver, mercury, and lead; and the nitrate and muriate of barytes.

V. Molybdenum unites readily with sulphur, and composes a substance, similar to the one from which the metal was originally obtained. One hundred parts of the metal combine with 67 of sulphur.

SECTION XXII.

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 molybdic acid.

II. Uranium is of an iron grey colour; and internally of a reddish brown. It has only been obtained in small grains of considerable hardness and lustre. Its fusion is very difficultly effected. It undergoes no change by exposure to air, unless strongly heated, when it burns, and becomes a black oxide.

III. The metal is soluble only in nitric acid.

IV. Its oxide, when precipitated by potash from nitric acid, is of a yellow colour, and dissolves in acids. It is precipitated by alkalies; and is thrown down, of a reddish brown colour, by prussiates. Sulphuret of ammonia gives a brownish yellow precipitate; and tincture of galls, a chocolate brown one. When exposed to intense galvanic action, it is fused, but not reduced.

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

There appear to be two oxides of uranium, the *yellow* one, which retains its colour when heated alone, and becomes the *black* oxide, when heated with a little oil. The first, according to Bucholz, consists of 80 metal and 20 oxygen; but the composition of the black oxide is not yet determined.

SECTION XXIII.

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 is a very difficult one,

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[*] Berzelius, Ann. de Chim. et Phys. iii. 161

and frequently fails of success. Professor Clarke has succeeded in effecting its reduction by the oxygen and hydrogen blow-pipe.*

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. Other methods of forming tungstic acid are described by Bucholz.†

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. Bucholz makes it the mean of these two numbers, viz. 17.4. It is only, therefore, surpassed in density by gold and platinum.

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; has the specific gravity 6.12; is difficultly fusible except by intense Galvanic action, which partially reduces it; it is insoluble in water; but remains suspended in it, and in this state has no action on vegetable colours. Exposed to heat in a platinum 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 induced Vauquelin to withdraw it from the class of acids, and to arrange it among the oxides.

The tungstic acid is composed, as appears from the experiments of Bucholz, of 20 parts oxygen and 80 metal; and the tungstate of lime was shown by Klaproth, to contain per cent. 77.75 parts of acid, and 22.25 of lime.

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* Thomson's Annals, x. 376.

† Thomson's Annals, vi. 198.

FOURTH CLASS.

REFRACTORY METALS.

SECTION XXIV.

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. To free it from iron, Laugier dissolved it in muriatic acid, and added oxalic acid, which separates a white flocculent precipitate of oxalate of titanium.* The oxalic acid in this may be destroyed by calcination.

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 fuses, but is not reduced by a powerful Galvanic battery. It is reduced, however, 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 reddish 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 reddish 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 oxi-

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* 89 Ann. de Chim. 306

dized 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 XXV.

Columbium and Tantalum.

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 was not reduced by Mr. Hatchett, who however, from its properties, entertained 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 alkalies: and both solutions are colourless. Prussiate of potash gives an olive-coloured precipitate; tincture of galls, a deep orange; and hydrosulphuret of ammonia, one of a chocolate colour.

Tantalum.

This metal was discovered by Mr. Ekeberg, a 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.* 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 tantalum. The following are the characteristic properties of tantalum, as enumerated by Mr. Ekeberg:

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

2. Fixed alkalies attack it when fused with it in considerable excess, and dissolve a considerable quantity, which may afterwards be precipitated by acids, even by the carbonic.

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* See Annales de Chimie, xliii. 281.

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 tantalum, 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 tantalum in fixed alkalies, 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 had been entertained by several chemists, whether any essential difference exists between columbium and tantalum; and their identity appears now to be sufficiently established by the experiments of Dr. Wollaston. Having procured specimens of the tantalite and yttro-tantalite, from which tantalum 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 manganese, 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. Ekeberg, however, we are informed by Berzelius,* discovered in a sample of the mineral from the British Museum, a considerable quantity of tungstic acid, to which it owes its acid properties, and its other constituent he found, with Dr. Wollaston, to be oxide of tantalum.

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 tantalum, with the characteristic ingredient of columbium.

Tantalum has lately been reduced to a metallic form by Berzelius. His method consisted in introducing the oxide, which had previously

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* Thomson's Annals, iv. 467.

been strongly heated, into a cavity about one inch and a half deep, and of the size of a goose quill, artificially formed in a piece of charcoal. To this cavity a stopper of charcoal was fitted, and the whole, enclosed in a Hessian crucible, was exposed to a violent fire during an hour. From four experiments, similarly conducted, he inferred the composition of the oxide to be

Tantalum	94.8	100.
Oxygen	5.2	5.485
	100.	

The specific gravity of a specimen of the metal, sent by Berzelius to this country, was found by Dr. Wollaston to be 5.61, but as the mass was porous, its specific gravity is probably much higher. Its colour was dark grey, and when scratched with a knife, or rubbed against a fine grindstone, it assumed the metallic lustre, and the appearance of iron. By trituration, it was reduced to a powder, which was destitute of metallic lustre, and completely insoluble, even by several days digestion, in muriatic, nitric, or nitro-muriatic acid. Like chrome, titanium, iridium, and rhodium, it is incapable, therefore, of being oxidized by acids, and in order to be oxidized requires to be fused with caustic potash. At a red heat, the metal takes fire, and burns with a feeble flame. It detonates, also, when mixed with nitre, and projected into a red-hot crucible. With other metals, it unites and forms alloys.*

SECTION XXVI.

Cerium.

I. Cerium was discovered, by Messrs. Berzelius and Hisinger 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 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.†

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; or, as Laugier recommends, by oxalic acid. This precipitate, well washed, and afterwards calcined, is the

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* Ann. de Chim. et Phys. iii. 140; Thomson's Annals, viii. 233.

† See Nicholson's Journal, xii. 105.

oxide of cerium. The white oxide has been recently determined by Hisinger,[*] to consist of

Cerium	85.088	100.
Oxygen	14.912	17.41
	100.	

And the red or peroxide is composed of

Cerium	79.29	100.
	20.71	26.115
	100.	

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. The dry salt consists of 100 parts of muriatic acid united with 197.5 of oxide of cerium.

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. It contains per cent. 57.9 parts of protoxide, 19.1 of water, and 23 of carbonic acid.

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.

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[*] Thomson's Annals, iv. 357.

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 reddish, 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. When exposed by Mr. Children to his powerful Galvanic battery, oxide of cerium fused; and, when intensely heated, burned with a large vivid white flame, and was partly volatilized. The fused oxide, on exposure for a few hours to the air, fell into a light brown powder, containing numerous shining particles of a silvery lustre.

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 XX.

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, cause 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 distinction (as has been well observed by Berzelius[*]) between inorganic and organic compounds appears to be this. The former are composed either of combustible or of oxidized bodies; and, when when of the latter, each combustible base is united with a portion of oxygen, which belongs exclusively to it, and which accompanies it, when it is detached from combination. Organic compounds, also, contain oxygen; but, in these, we have several combustible bases, united to one portion of oxygen, which cannot be said to belong more to the one, than to the other; and which would not suffice to bring any one of those bases to its maximum of oxidation.

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[*] 80 Ann. de Chim. 37.

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 destructive distillation of vegetables was, till lately, the only method employed to determine the proportion of their ultimate elements; but more refined and perfect modes of analysis have lately been practised by Gay Lussac and Thenard, which have afforded results, much more deserving of confidence.* Their process consists in effecting the combustion of vegetable substances, in close vessels of a peculiar construction, by means of hyper-oxymuriate of potash. Berzelius, also, has considerably improved the methods of vegetable analysis.

The following general laws, respecting the composition of vegetable bodies, have been deduced, by Gay Lussac and Thenard, from a general review of their experiments.

I. A vegetable substance is always acid, when the oxygen, which it contains, is to the hydrogen, in a proportion greater than is necessary to compose water.

II. A vegetable substance is always resinous, or oily, or alcoholic, &c. when the oxygen, contained in it, is to the hydrogen, in a less proportion than in water.

III. A vegetable substance is neither acid nor resinous, but in a state analogous to sugar, gum, starch, lignin, &c. whenever oxygen and hydrogen enter into its composition in the same proportions as in water.

Without supposing then, that oxygen and hydrogen exist, as water, in vegetables, we may, for the sake of illustration, consider vegetable acids, as constituted of carbon, water, and oxygen;—the resins, alcohol, ether, &c. as composed of carbon, water, and hydrogen;—and bodies of the third class, as composed of carbon and water only. It should not, however, be concealed that some exceptions to the generality of these principles have lately been pointed out by Saussure.†

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.

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* Recherches Phys. Chim. ii.

† Thomson's Annals, vi. 431.

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 Extract 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, at a temperature below 212°, an infusion of saffron, prepared with boiling distilled water. Extract, thus procured, has the following properties:

1. It is cohesive, of a brownish colour, and generally of a bitterish 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 opaque. 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 alkalies, but neither in ether nor in acids, which last even precipitate it from its solution in water.

6. Oxy-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 woollen thread, previously impregnated with a solution of alum, is boiled with a solution of extract, the thread is dyed 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 Sir H. 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 series of experiments on this subject, Dr. Bostock is disposed to doubt whether there be any distinct principle, to which the title of *extract* can with propriety be given; and this doubt is entertained, also, by Braconnot.[*] 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;[†] but it has been the subject of a series of experiments by Bouillon la Grange and Vogel, who have given it the name of *polychroite*, on account of the many different colours which it is capable of assuming. Thus its natural colour is yellow; and its aqueous solution is deprived of colour by exposure to the sun's rays. Sulphuric acid dropped into the aqueous solution causes a deep indigo blue colour; nitric acid a green one; and chlorine renders it colourless.[‡]

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[*] Thomson's Annals, xii. 34.

[†] See Nicholson's Journal, xxiv. 204.

[‡] Ann. de Chim. lxxx. 188.

SECTION II.

Mucilage, or Gum.

THIS substance, termed mucilage when fluid, is, in a solid state, 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 a 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. Its specific gravity varies from 1300 to 1490.

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 precipitates it from water.

4. It is separated 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. According to Dr. Thomson's experiments, the salts, containing mercury and iron at the maximum of oxidation, 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 investigated by Dr. Bostock;[*] and have been found to vary considerably in the different species of gum; for example, in gum arabic, cherry-tree gum, and linseed mucilage. Berzelius, also, has examined the compound of gum arabic with oxide of lead, to which he has given the name of *gummate of lead*. He finds it to consist of

Gum	61.75	100.
Oxide of lead . .	38.25	62.105
	100.[†]	

5. Gum is soluble in pure alkalies, 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,

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[*] See Nicholson's Journal, xviii. 28.

[†] 95 Ann. de Chim. 77.

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, deposits a little saccholactic or mucous acid. The production of *mucous* acid appears to be the characteristic property of mucilage; and Vauquelin even obtained this acid from the mucilage of linseed. Some malic acid is also formed; and by continuing the heat, the gum is changed by the nitric acid 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 critic 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, which has been already referred to. Cherry-tree gum, tragacanth, and some other varieties are considered as forming a distinct vegetable substance, to which the name of *cerasin* has been given. It imbibes water, and swells very considerably in bulk, but is not at all soluble except in boiling water, from which it again separates on cooling in the state of a jelly.

Gum arabic has been analyzed by Gay Lussac and Thenard, and by Berzelius, and found to consist of

Carbon	42.23	41.906
Oxygen	50.84	51.306
Hydrogen	6.93	6.788
	100.†	100.‡

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

† Gay Lussac.

‡ Berzelius.

Saussure in addition to these three elements found also a minute quantity of nitrogen. From gum arabic and gum tragacanth, he obtained

Carbon	45.84
Oxygen	48.26
Hydrogen	5.46
Azote	0.44
	100.[*]

SECTION III.

Vegetable Jelly.

Vegetable jelly may be obtained from the recently expressed juices of certain fruits, suchas the currant and gooseberry. When 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 alkalies. 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 Saccharifera.* 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 re-

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[*] Thomson's Annals, vi. 431.

moved. 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 lime-water, 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, beside a proportion of uncrystallizable syrup. In Germany, the expense has been calculated at about three pence *per* pound; but this estimate is probably under-rated.*

From the experiment of Proust,† it appears that a coarse sugar may be procured from grapes (of which many thousand tons are annually

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* See Chaptal on the manufacture of sugar in France, Phil. Mag. xlvii. 331.

† Nicholson's Journal, xxi. 356.

wasted in Spain,) at the expense of about eight pence *per* pound; or, under favourable circumstances, even for five pence. In apples and pears, in the juice of liquorice, and in some other vegetable juices, sugar exists, but in a state of combination, which prevents it from assuming a crystallized form.

The sugar of grapes has been analyzed by Saussure, and found to contain very nearly the same proportions of ingredients as starch sugar, stated under the article *fecula.*[*] These two kinds of sugar agree, indeed, so closely as to their properties, that they probably constitute one species. Sugar from the cane and from beet differs from these, and from all other kinds of sugar, by containing a greater proportion of carbon.[†]

Sugar is produced also in the process of malting, which consists in the conversion of starch 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, deposits large crystals of sugar.

3. Lime-water renders sugar more soluble; and, reciprocally, sugar increases the solubility of lime. Alkalies 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.[‡]

6. Sugar has the property of decomposing several of the metallic salts, when boiled with their solutions. Sometimes it reduces the oxide to a metallic state, as in sulphate of copper. In other instances, as in the acetate of the same metal, it merely reduces the oxide to an inferior degree of oxidation.[§] With oxide of lead, it forms an insoluble compound, called by Berzelius *saccharate of lead.*[‖]

7. 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: Gay Lussac, Thenard, and Berzelius, have analyzed it by combustion with hyper-oxymuriate of potash, and Dr. Prout by distillation with oxide of copper. They find it to consist of

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[*] See Sect. ix. *infra.*

[†] Thomson's Annals, vi. 428.

[‡] Thomson's Chemistry, iv. 214.

[§] Vogel in Thomson's Annals, vii. 42.

[‖] 95 Ann. de Chim. 53.

Carbon	42.47	44.200	39.99
Oxygen	50.63	49.015	53.33
Hydrogen	6.90	6.785	6.66
	100.[*]	100.[†]	100.[‡]

Or of carbon	42.47
Oxygen and hydrogen, in the same proportion as in water	57.53
	100.

It is remarkable that these are as nearly as possible the proportions of the ingredients of gum arabic.

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*). Sugar 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, also, 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.

[*] Gay Lussac.

[†] Berzelius.

[‡] Prout.

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. The constitution of oxalic acid, has been investigated with much skill and attention by Dr. Thomson.* 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

Oygen	64
Carbon	32
Hydrogen	4
	100

Oxalic acid has since been analyzed by Gay Lussac and Thenard,† and by Berzelius.‡ The first mentioned chemists decomposed oxalate of lime of known composition by oxy-muriate of potash, and obtained the following results:

Carbon	26.566
Oxygen	70.689
Hydrogen	2.745
	100.

Or the analysis may be thus stated:

Carbon	26.566
Oxygen and hydrogen in the same proportions as in water	22.872
Excess of oxygen	50.562
	100.

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[*] Philosophical Transactions, 1808.

[†] Recherches, ii.

[‡] 81 Ann. de Chim. and Thomson's Ann. iv. 232, and ix. 33.

Berzelius, some time ago, ascertained that of the water, which enters into crystallized oxalic acid, only 28 per cent. can be driven off by heat, but that a farther quantity may be detached, by uniting the acid with oxide of lead. Taking the latter portion into account, the crystals consist of 58 acid and 42 water; and the real acid is thus constituted, according to his experiments:

Oxygen	66.211 . . .	= 6 atoms.
Carbon	33.021 . . .	= 4 atoms.
Hydrogen . . .	0.728 . . .	= 1 atom.

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, called super-oxalate or binoxalate 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.

According to Berzelius 100 parts of potash are united, in the oxalate, with 97.3 parts of oxalic acid, and in the binoxalate, with 192.4. Exclusively of water, which, in the crystals of the oxalate, amounts to 17.31 per cent., they are composed as follows:

	Acid.	Base.
Oxalate of potash . . .	49.32 . . .	50.68
Binoxalate of ditto . .	65.80 . . .	34.20

Quadroxalate of potash may be composed in several methods.* It 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 $4\,x$.

Berzelius determined that, in this salt, 100 parts of potash are combined with 380 parts of oxalic acid, or it consists of

Potash	18.95
Acid	72.05
Water	9.
	100.

Salt of sorrel was found by Berard to be a true quadroxalate of potash.

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* See Berard, 73 Ann. de Chim. 271.

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 forms, also, with oxalic acid, a *binoxalate,* but no *quadroxalate.* In the oxalate, 100 parts of soda are combined with 143.5 parts of acid; in the binoxalate with 284.7, according to the analysis of Berzelius.

Oxalate of ammonia crystallizes in long transparent prisms, rhomboidal, and terminated by dihedral summits, which, according to Berard, contain 13 per cent. of water. 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.

In oxalate of ammonia, 100 parts of real alkali are united with 261 parts of acid. A super-oxalate or *binoxalate* of *ammonia,* also, exists, which is less soluble in water than the oxalate. In this, 100 parts of base are united with 523 of acid.

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 first to neutralize any excess of acid.

Oxalates of barytes and strontites are white tasteless powders of very sparing solubility; but these earths, with an excess of acid, form more soluble super-oxalates.

One hundred parts of strontites take 83.62 of oxalic acid for saturation. No super-oxalate exists with this base. The oxalate of barytes is more soluble than the strontitic salt. It consists of 100 parts of base, united with 60.84 acid. A super-oxalate may be formed, by heating muriate of barytes with oxalic acid. This salt, which shoots into crystals, has its elements so feebly combined, that it is decomposed by mere solution in water. It is constituted of 100 parts of base and 123 of oxalic acid.

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. It is composed of 100 parts of base and 265 of acid.

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 *per* Thomson of		Consist *per* Berard of	
	Acid.	Base.	Acid.	Base.
Oxalate of ammonia	74.45	25.55	[*]62.34	27.66
——— magnesia	73.68	26.32	72.65	27.35
——— soda	63.63	36.37	58.92	41.08
——— lime	62.50	37.50	62.00	38.00
——— potash	44.87	55.13	49.32	50.68
——— strontian	39.77	60.23	45.54	54.46
——— barytes	41.16	58.84	37.83	62.17
——— lead	25.20	74.80		
——— ——	24.54	75.46[†]		

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.

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

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[*] This number should probably be 72.34; for, as it stands in the Table, the acid and base do not make up 100.

[†] Berzelius, 94 Ann. de Chim. 180.

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, and with variable proportions of malic and sometimes of acetic acid. The process, for obtaining it in a separate state, we owe to the ingenuity of Scheele. To the expressed 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 chalk 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, allow 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 1.85 or thereabouts, equal to the weight of the chalk which has been employed, and previously diluted with 10 parts of water.—Let the acid and precipitate remain together 24 hours; during which time they must be frequently stirred with a wooden spatula. 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 first in a leaden boiler, and afterwards in shallow earthen dishes, placed in a sand-heat. Reduce the liquor to about one-fourth of 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. 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 be 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 17¼ 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 41¼ 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 3½ ounces, or 28 drachms, of pretty large crystals; from whence it follows that the whole 7½ ounces would have given 4 ounces 3 drachms of citric acid.*

The preparation of solid citric acid on the large scale of manufacture requires an attention to a number of minute circumstances, which are stated at length by Mr. Parkes in the 3d volume of his Chemical Essays, or in the 46th volume of the Philosophical Magazine.

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 considerably. I have found it as high as twelve avoirdupois ounces; but about six or eight ounces to the wine gallon is a fair general average. The only method of ascertaining its proportion consists in adding, to a quantity of the juice, solution of pure potash till saturation is produced. Liquid potash, of a fit strength for this purpose, may be prepared by boiling two pounds of American potash with one pound of quicklime, previously slaked to a thin paste, and a gallon of water, in an iron pot, during half an hour. The solution may be strained through calico, and reserved for use in well stopped bottles. When employed as a test, one measure may be added to three measures of water; and it is proper to ascertain, by experiment, how much of this solution is requisite to saturate an avoirdupois ounce of white crystals of citric acid. It will then be easy, by saturating with the same alkaline liquor, an aliquot part of a wine gallon of any sample of lime or lemon juice (judging of the point of saturation by test papers) to calculate what quantity of solid acid is contained in a gallon of the juice under examination. This, of course, implies that the juice is not contaminated with any other 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 contain per cent., according to Berzelius,

Real acid	79
Water	21
	100

Only a small part of this water, viz. about 7 per cent., can be driven off by a degree of heat, just below what is sufficient to decompose the acid. The real proportion of water can only be determined, by uniting the acid with some basis, oxide of lead for example.

Citric acid is decomposed at a high temperature, and yields products, which are constituted of carbon, hydrogen, and oxygen in un-

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* Philos. Magazine, x.

certain proportions. A better method of effecting its analysis is that practised by Gay Lussac and Thenard, viz. combustion with hyper-oxymuriate of potash. By this process, they determined it to consist of

Carbon	33.811
Oxygen	59.859
Hydrogen	6.330
	100.

Berzelius obtained results, differing considerably from these; owing, he believes, to the want of due allowance, by Gay Lussac and Thenard, for the quantity of water of crystallization. His proportions are

Carbon	41.369
Oxygen	54.831
Hydrogen	3.800
	100.*

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 oxalic is diminished, till at length it disappears altogether, and acetic acid appears to be formed.

Citric acid readily unites with alkalies, 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 bi-carbonate of potash: and the result is an extremely soluble and even deliquescent salt, composed of 55½ acid and 44½ 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 was found by Gay Lussac and Thenard to consist of

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* Ann. de Chim. xciv. 172.

Acid	68.83
Lime	31.17
	10C.

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. Citrate of lead has been analyzed by Berzelius, and found to consist of

Acid	34.18	100
Protoxide of lead	65.82	190

ART. 2.—*Gallic Acid.*

The acid exists in the gall-nut, along with tan and other substances. In Sir H. Davy's experiments, 400 grains of a saturated infusion of galls, gave, by evaporation, 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 contain both tan and gallic acid.* To purify them, they must be dissolved in alcohol, and the solution cautiously evaporated to dryness.

Gallic acid 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.

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 M. 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 com-

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* Berzelius, 94 Ann de Chim. 303.

bines 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 Sir H. 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; but Berzelius denies its action on the colour of turnsole. It effervesces with alkaline carbonates, but not with earthy ones.

5. Nitric acid converts the gallic into oxalic acid.

6. It unites with alkaline solutions without producing any deposit; but from watery solutions of lime, barytes, and strontites, it occasions a bluish 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, 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.†

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

† 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 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 the 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. A strong objection to this process is that the juice of apples contains not only malic but sorbic acid, which also gives with lead an insoluble salt.

Vauquelin has shown that the malic acid may be obtained advantageously from the juice of house-leek (*sempervivum tectorum*) by adding acetate or nitrate of lead, and decomposing the insoluble malate with sulphuric acid, added in slight excess. To remove the redundant sulphuric acid, Gay Lussac boils the liquor with a small quantity of litharge, and throws down the oxide of lead by a current of sulphuretted hydrogen. He then evaporates to the consistence of syrup, and adds alcohol, which separates the malic acid from a portion of malate of lime. The alcohol is then distilled at a gentle heat, and the residue dissolved in water. 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. This process Mr. Donovan finds to be extremely uncertain and costly.

The malic acid is liquid, and incapable of being crystallized; for, when evaporated, it becomes thick and viscid, like syrup. It is scarcely possible to obtain it free from colour. It is very soluble in water. By keeping, it undergoes a kind of decomposition. Nitric acid converts it into oxalic acid. It unites with alkalies 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. When perfectly pure, Gay Lussac has shown that it does not decompose either nitrate of silver or nitrate of lead.*

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* Ann. de Chim. et Phys. vi. 330.

Art. 4.—*On the Sorbic Acid.*

This acid was discovered by Mr. Donovan in the juice expressed from the berries of the *sorbus aucuparia*, or service-tree;* and its claim to be considered as a distinct acid has been established, not only by his experiments, but by the subsequent examinations of Vauquelin and Braconnot.† It had escaped the sagacity of Scheele, who had overlooked its existence not only in the juice of the *sorbus*, but in that of apples, of which it forms the principal ingredient; and Braconnot has found it, also, in the juice of unripe grapes.

The fruit of the *sorbus*, collected about the month of October a little before it is perfectly ripe, is to be bruised in a porcelain or marble mortar, and submitted to a strong pressure. Vauquelin recommends that the juice, thus obtained, should be allowed to remain 12 or 15 days in a moderately warm place. By the fermentation, which it thus undergoes, a quantity of viscid matter is deposited, which may be separated by filtration. The clear liquor may be mixed with a solution of acetate of lead, which affords a copious precipitate. This is to be washed on a filter, first with a large quantity of cold water, to free it from colouring matter; and next with repeated quantities of boiling water, the hot washings only being reserved in a series of glass jars. After some hours, they become opaque, and deposit crystals of singular lustre and beauty, resembling benzoic acid. Those, which have been formed in the colourless washings, are to be collected on a filter, dried in the air, and preserved for a subsequent process.

The original mass, remaining on the filter, is next to be boiled for half an hour with a slight excess of diluted sulphuric acid; and when cold is to be filtered. The clear liquor is to be mixed, a second time, with acetate of lead; the precipitate washed as before with boiling water; and the crystals selected from the colourless washings only. The remaining mass is again to undergo the action of sulphuric acid as before.

The crystals, thus collected, are to be boiled for half an hour with 2.3 their weight of sulphuric acid of the specific gravity of 1090, supplying water as it evaporates, and taking care to keep the materials suspended, by stirring constantly with a glass rod. The clear liquor is to be filtered off, and poured into a tall and narrow glass jar. While still hot, sulphuretted hydrogen gas is to be passed through it, till all the lead has been precipitated. The fluid is then to be filtered, and boiled in an open vessel, until the vapour ceases to blacken paper, on which characters have been traced with acetate of lead.

The acid liquor thus obtained, when evaporated to a syrup, shoots on cooling into mamillary crystals, which have a very sour taste, and deliquiate in a moist atmosphere.

Braconnot prefers obtaining the acid by the intermediation of lime rather than of oxide of lead, by which process he procures a larger proportion of acid.‡ In the juice of the *sorbus*, he finds that the peculiar acid is not pure, but mixed with malic acid.

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* Phil. Trans. 1815.

† Ann. de Chim. et Phys. vi.

‡ Ann. de Chim. et Phys. vi. 241.

The sorbic acid, when submitted to distillation, melts and yields acid vapours, and finally sublimes in white needle-shaped crystals, which are intensely sour, and are the acid somewhat altered.

The watery solution of sorbic acid does not precipitate lime-water or barytes-water. From acetate of lead it throws down a white flocculent precipitate, which, on standing, assumes a crystalline form. This is one of its most distinctive characters.

It agrees, to a certain extent, with the tartaric acid in forming salts, which become less soluble by increasing their proportion of acid. But the capacity of saturation is greater in the tartaric acid, which saturates a quantity of base containing 11.94 of oxygen, while the sorbic saturates a quantity equivalent only to 11.

The sorbates have been examined by Mr. Donovan, and more fully by Braconnot, whose memoir contains a detailed account of their properties and composition.

The sorbic acid has been analyzed by Vauquelin, by combustion with oxide of copper, and its composition is stated to be

Hydrogen	16.8
Carbon	28.3
Oxygen	54.9
	100.

ART. 5.—*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 spoonful, 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 decomposition by muriate of lime doubles 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 liberty 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. 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. The crystals were found by Berzelius to consist of

Real acid	88.75
Water	11.25
	100.

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 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.*

Tartaric acid has been analyzed by Gay Lussac and Thenard, and by Berzelius; and their results are contained in the following Table. One hundred parts consist,

	Carbon.	Oxygen.	Hydrogen.
According to Gay Lussac, of .	24.050 . .	69.321 . .	6.629
———— Berzelius, of . .	35.98 . .	60.28 . .	3.74

The disagreement of these results arises, probably, from the omission of part of the water of crystallization in the estimate of the two first-mentioned chemists.

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. Mr. R. Phillips finds that 100 parts of cream of tartar require for neutralization 43½ of sub-carbonate of potash. The resulting salt is very soluble, and even deliquescent. It is composed, according to Berzelius, of

Acid	58.69	100.
Base	41.31	70.4
	100.	

Super-tartrate, or bi-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 bi-tartrate of potash.

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

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, the form of which has been described by Dr. Wollaston.[*] These crystals, by being reduced into powder, become the *cream of tartar* of the shops.

Bi-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 deposits the salt on cooling in such quantity as amounts almost to precipitation.

Bi-tartrate of potash, it is observed by Gay Lussac[†], acts, in many cases, like a simple acid, and even dissolves oxides that are insoluble in the mineral acids and in the tartaric acid. He proposes its use, therefore, in mineral analyses.

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

Acid	70.45	100.
Potash	24.80	35.2
Water	4.75	
	100.	

This small portion of water appears to be essential to the salt; for it cannot be separated by heat, without decomposing the acid. When 100 grains of the salt are incinerated, so as to destroy the acid, the alkali obtained is exactly sufficient to neutralize 100 grains of the bi-tartrate; a proof that the potash in the acidulous salt is combined with twice as much acid, as in the neutral compound.

By the destructive distillation of bi-tartrate of potash, Fourcroy and Vauquelin obtained, exclusively 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 24 parts of cream of tartar with 18 parts of 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. Tartrate of lime consists of 77½ acid and 22½ base; and tartrate of lead of 37½ acid and 62½ oxide.

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[*] Thomson's Annals, x. 37.

[†] Ann. de Chim. et Phys. iii. 281.

[‡] Ann. de Chim. lxiv. 48.

ART. 6.—*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 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 19-20ths of what it had dissolved. It is soluble in alcohol.

The composition of this acid has been ascertained by Berzelius, as follows:

Carbon	74.41
Oxygen	20.43
Hydrogen	5.16
	100.

The compounds, which it forms with alkaline and earthy bases, called BENZOATES, are fully described by Hisinger in the 40th volume of the Philosophical Magazine, and by Berzelius in the 90th volume of the Annales de Chimie.

ART. 7.—*The Oxalic Acid*

Is also found native in the juice of sorrel, forming a quadroxalate, and, as appears from the experiments of Vauquelin, in the Rheum Palmatum.

ART. 8.—*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.*

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* See Nicholson's Journal, 8vo. vii. 129.

ART. 9.—*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 reddish 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. 10.—*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 experiments of Saussure.*

ART. 11.—*The Prussic Acid*

Has been discovered in water distilled from bitter almonds, from the leaves of the laurel, and from peach blossoms, and in the bark of the *prunus padus.* 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.† The properties of the prussic acid will be described in the chapter on animal products.

ART. 12.—*Boletic Acid.*

This acid was first obtained by Braconnot, from the juice of the *boletus pseudo-ignarius.*‡ The juice was boiled, filtered, and evaporated cautiously, to the consistence of syrup. This was repeatedly digested in alcohol; the insoluble portion was dissolved in water, and precipitated by nitrate of lead. The white precipitate, thus obtained, was mixed with water, and decomposed by sulphuretted hydrogen gas. The liquid, being evaporated, yielded crystals of *boletic acid.* The crystals, when purified by solution in alcohol, and re-crystallization, are white, and have the shape of irregular four-sided prisms.

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* Nicholson's Journal, xxv. 279.

† Annales de Chimie, xlv. 206.

‡ Thomson's Annals, ii. 469.

They require 180 parts of water at 68° to dissolve them, and 45 parts of alcohol. The aqueous solution reddens vegetable blues, precipitates nitrate of lead; and throws down the peroxide, but not the protoxide of iron from its solutions. Nitrates of silver and mercury afford with it a white precipitate.

With the alkalies and earths, it unites, and forms a class of salts, which may be called *boletates.*

ART. 13.—*Acid discovered by Braconnot.*

An acid of a peculiar nature was discovered some years ago, by Braçonnot, in vegetable substances,* which have undergone the acetous fermentation. He first procured it from rice, which had been left, mixed with water, at a gentle heat, till it had become sour. When drained in a woollen bag, a liquid passed through, which gave acetous acid by distillation. Continuing the evaporation, almost to dryness, a gummy substance was left, having a decidedly acid taste. This was digested in alcohol, and the solution, evaporated to the consistence of syrup, became a granular crystalline mass, with a strongly acid taste. It still, however, contained a salt with base of lime. The excess of acid was, therefore, neutralized by oxide of zinc; the salt obtained was decomposed by barytes; and the barytes precipitated by sulphuric acid. The liquor, being now carefully evaporated to a syrup, left an uncrystallizable, almost colourless, acid, nearly as strong to the taste as the oxalic.

With potash and soda, this acid gave deliquescent salts, soluble in alcohol; and, with ammonia, a crystallizable salt. It formed, with lime, a salt, which required 21 times its weight of water for solution; with strontites, a salt soluble in 8 parts of water; with barytes a gummy substance; and, with magnesia, small granular crystals, which were not soluble in less than 25 parts of water.

Dr. Thomson, in the 5th edition of his System of Chemistry, has proposed for this acid the name of ***Zumic Acid***, from ζυμη, leaven.

ART. 14.—*Rheumic Acid.*

A new acid was announced by Mr. Henderson as existing in the stems of garden rhubarb; but as he candidly admits the possibility of fallacy, and as his discovery has not been confirmed by the subsequent experiments of Mr. Donovan, it may be sufficient to refer to their respective papers in Thomson's Annals, viii. 247, and ix. 103.

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* 86 Ann. de Chim. 84.

ART. 15.—*Kinic Acid.*

When yellow Peruvian bark is macerated in cold water, and the infusion concentrated and set apart for some time in an open vessel, a salt crystallizes from it in square or rhomboidal plates; having no taste; soluble in five parts of cold water; and insoluble in alcohol. From this salt, first obtained by M. Deschamps, jun. of Lyon, Vauquelin separated the lime by oxalic acid, and concentrated the remaining liquor to the consistency of a syrup, which he set aside for a week, when, on touching it with a glass rod, it crystallized at once into divergent plates. Its colour was slightly brown; its taste extremely acid and rather bitter; and it was readily soluble in water. It is distinguished from other vegetable acids by its forming a soluble salt with lime, and by its not precipitating silver or lead from their respective solutions.*

SECTION VI.

Fixed Oils.

1. THESE oils are obtained, by pressure, from certain vegetables; as the olive, the almond, linseed, poppy-seed, rapeseed, &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 water, 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. The expressed oils of linseed and of olives, Mr. Brande finds, are very sparingly soluble in alcohol of specific gravity .820. Four ounce measures of alcohol dissolve a drachm of linseed oil. Castor oil is perfectly soluble in every proportion in alcohol of .820, but not in weaker alcohol.†

6. Four ounce measures of sulphuric ether of specific gravity .7563 are capable of dissolving a fluid ounce and quarter of oil of almonds; a fluid ounce and half of olive oil; and almost any proportion of castor oil. (Brande.)

7. 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.

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* Ann. de Chim. lix. 162.

† Phil. Trans. 1811, p. 265.

8. They unite with alkalies, and form soap. The soap, however, which is commonly manufactured in this country, is made by combining the fixed alkalies 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. A memoir of Chevreul on the Combination of Alkalies with Fat may, also, be consulted in the 88th and 94th volumes of the *Annales de Chimie,* and a paper of Colin on the manufacture of hard soap is contained in the 3d vol. of *Annales de Chimie et de Physique.*

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

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

10. Their properties are changed by boiling with metallic oxides, those of lead for example. The mucilage unites with this 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.

11. 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.

12. 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 Sir H. 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. Sir H. 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.[*] But decisive proof of the

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[*] Philosophical Transactions, 1808.

presence of oxygen in oil has lately been supplied by Gay Lussac and Thenard's analysis of olive oil, which they find to be composed of

Carbon	77.213
Oxygen	9.427
Hydrogen	13.360
	100.

The analysis may also be stated as follows:

Carbon	77.213
Oxygen and hydrogen in the proportions to form water	10.712
Excess of hydrogen	12.075
	100.

13. 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. Oxymuriatic acid gas, passed through them, thickens them, and renders them tenacious like wax.

14. 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; but if the distilled water be long kept, Bucholz finds that the oil is converted into mucilage.

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.

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* See Journal of Science, &c. v. 367.

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

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 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-oxymuriate of potash, and take fire when poured into oxymuriatic acid gas.

8. Essential oils are thickened by long exposure to air. This is owing, as Dr. Priestley 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 soluble in 100 times their weight of cold, or in 11 times their weight of boiling 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 about six times their weight of cold alcohol, or to any amount in boiling alcohol; and are not precipitated by water. With alkalies and earths they compose a class of salts called camphorates. Fifty grains of the acid are saturated by 28 of carbonate of lime = 15.7 pure lime.

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.

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* Bucholz, 84 Ann. de Chim. 301.

† Thenard, Mémoires d'Arcueil, ii.

SECTION VIII.

Resins.

Resins are the inspissated juices of certain plants, and are generally obtained by wounding their bark. Copal, or lac, may be taken 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 alkalies act on them; the pure alkalies 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 to between a fifth and a third the weight of the resin which has been employed; whereas, by incineration in close vessels, scarcely 1-100th 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.‡

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 remain-

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* See 69 Ann. de Chim. 293.

† The reader, who may wish for further information respecting the gum-resins, may consult Braconnot's Memoir in the 28th vol. of Nicholson's Journal; and Pelletier's in the 80th vol. of Annales de Chimie.

‡ Philosophical Transactions, 1806.

der 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 alkalies, &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.

Berzelius states the composition of the succinic acid as follows:

Hydrogen	4.512
Carbon	47.600
Oxygen	47.888
	100.†

SECTION IX.

Farina, Starch, or Fecula.

STARCH may be obtained from the flour of most varieties of grain, from the roots of the potato, 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 to be 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

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* Useful directions for this process are given by Robiquet and Colin, Ann. de Chim. et Phys. iv. 326.

† 94 Ann. de Chimie, 189.

‡ Repertory of Arts, iii. 383. The analysis of several varieties of the potato by Lampadius may be seen in Thomson's Annals, v. 39.

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

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. Its proportion in sound and unsound grain, and the causes of unsoundness in corn and flour, have been ably investigated by Mr. E. Davy, in a memoir published in the 49th volume of the Philosophical Magazine. Of rice, it constitutes, according to Braconnot, from 83 to 85 per cent.[*]

Common starch, though not absolutely free from gluten, 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 alkalies 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.

The grain, from which malt is most commonly prepared, is barley. In this grain, Proust has discovered, beside the ingredients of wheat, a peculiar substance, nearly resembling saw-dust, in its external characters, to which he has given the name of *hordein*.[†] This substance may be separated from starch by the action of hot water, in which it is quite insoluble. During the process of malting, its proportion is considerably diminished, and it appears to be partly converted into sugar, or into starch, as will appear from the following comparative analysis of malted and unmalted barley.

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[*] Ann. de Chim. et Phys. iv. 383.

[†] Ann. de Chim. et Phys. v. 337.

	In 100 parts of barley.	In 100 parts of malt.
Resin	1	1
Gum	4	15
Sugar	5	15
Gluten	3	1
Starch	32	56
Hordein	55	12

It appears, then, that the formation of malt consists in the increase of gum, sugar, and starch, and the diminution of gluten and hordein. The starch, that remains after malting, is found changed in its properties; for it does not as before yield a viscid paste, capable of gelatinizing on cooling. The process of malting, is not, however, essential to the production of alcohol from grain; for in the Scotch distilleries it has long been common to use a large proportion of unmalted barley; and M. Clement, by direct comparative experiments, obtained equal quantities of alcohol by fermenting the infusions of equal weights of malted and of unmalted grain.* The spirit obtained from unmalted barley has a peculiar odour, which is owing to its holding in solution a yellow solid oil, separable by careful distillation† of the alcohol.

The loss of weight sustained by grain in malting, which Proust states at one-third, Dr. Thomson asserts is greatly over-rated, and that it did not, on an average of 50 processes, carried on under his inspection, exceed one-fifth. The hordein of Proust, he considers as starch under some modification, which is changed, by malting, partly into true starch, and partly into sugar.‡

Another method of converting starch into sugar was discovered by M. Kirchoff of St. Petersburg. The change is effected by the action of sulphuric acid, which is boiled, for many hours, with starch and water. The process has been successfully repeated by several persons, and among the rest by M. Vogel§ and by Dr. Tuthill of London.‖ The latter digested a pound and half of potato starch (obtained from 8¾ pounds of potatoes) six pints of distilled water, and a quarter of an ounce by weight of sulphuric acid, in an earthen vessel, at a boiling heat; the mixture being frequently stirred and kept at an uniform degree of fluidity by the supply of fresh water. In 24 hours there was an evident sweetness, which increased till the close of the process; at the end of 34 hours, an ounce of finely powdered charcoal was added, and the boiling kept up two hours longer. The acid was then carefully saturated by recently burned lime; and the boiling continued for half an hour, after which the liquor was passed through calico, and the substance, remaining on the drainer, washed repeatedly with warm water. This, when dry, weighed seven-eighths of an ounce, and consisted of charcoal and sulphate of lime. The clear liquor, being evaporated to the consistence of syrup, and set aside, was in eight days converted into a crystalline mass, resembling common brown sugar with a mixture of treacle. The saccharine

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* Ann. de Chim. et Phys. v. 422.

† Thomson's Annals, xii. 35.

‡ Annals of Philosophy, x. 389.

§ Ann. de Chim. l. 82.

‖ Nich. Jour. vol. 33.

matter, which Dr. Tuthill judged to be intermediate between cane sugar and grape sugar, weighed one pound and a quarter. By fermenting one pound of this substance in the usual manner, and distilling and rectifying the product, fourteen drachms by measure of proof spirit were obtained.

The differences between starch sugar, and common sugar from the sugar cane, have been pointed out by Nasse. Starch sugar assumes the form of spherical crystals like honey. It is not so hard, nor so sweet, nor so soluble in water, as common sugar. When it is digested with an alkaline cabonate, a precipitation of mucilage takes place: and the same precipitation is occasioned from a solution of starch sugar by muriate of tin. The solution of starch suger ferments without the addition of yeast, which is not the case with common sugar.[*]

It had been shown, by Professor de la Rive of Geneva, that in the formation of sugar from starch, no gas is evolved; that the alteration of the starch goes on in close vessels without the contact of air; and that no part of the sulphuric acid is either decomposed, or united to the starch as a constituent. These results have been confirmed by the experiments of Saussure,[†] who has shown, also, that the sugar which is obtained, exceeds, by about one-tenth, the original weight of the starch. He concludes, therefore, that the conversion of starch into sugar is nothing else than the combination of starch with water in a solid state, a conclusion which is strengthened by the results of analyzing those two substances, *viz.*

	Carbon.	Oxygen.	Hydr.	Azote.
In starch were found	45.39	48.31	5.90	0.40
In starch sugar	37.29	55.87	6.84	0.

In 100 parts of starch, the oxygen and hydrogen are sufficient to form 50.48 parts of water, with an excess of 3.76 oxygen. In starch sugar, the same principles exist in quantities sufficient to compose 58.44 parts of water, being an increase of nearly 8, and there is still an excess of 4.26 parts of oxygen.

7. Starch is said by Dr. Thomson to be capable of entering into chemical union with tan.[‡] Of the existence of such a combination, however, Dr. Bostock has found reason to doubt.[§]

8. Starch has been analyzed by Gay Lussac and Thenard, and by Berzelius, and the near coincidence of their results, obtained by different methods, is a strong presumption in favour of their accuracy. It consists,

	Carbon.	Oxygen.	Hydrogen.
According to Gay Lussac, of . .	43.55 . .	49.68 . .	6.77
————Berzelius, of . .	43.481 . .	48.455 . .	7.064

9. When strongly heated, starch becomes first yellow, and afterwards a reddish 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.* This

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[*] Thomson's Annals, vii. 47.

[†] Thomson's Ann. vi. 424.

[‡] Nicholson's Journal, 8vo. ix. 74.

[§] Nich. Journ. xviii. 33.

substance, however, Vauquelin finds, is not a true mucilage; for with nitric acid it gives only oxalic acid, and no mucous acid.*

10. When starch is distilled in close vessels, it yields an acid, which has been called the pyromucous, but which, in fact, is nothing more than vinegar, with an admixture of empyreumatic oil.

11. When starch and iodine are triturated together, both in a dry state, the starch assumes a violet tint, which passes to blue or to black, according to the proportions that are employed. The colour of this *ioduret or iodide of starch* is reddish, if the starch be in excess; a beautiful blue, when the two bodies are in due proportion; and black, when the iodine prevails. This compound is soluble in diluted sulphuric acid, and the liquor is of a fine blue colour. Concentrated sulphuric acid, also, dissolves it, and the solution is brown, but passes to a beautiful blue on the addition of water. There is also a *subioduret* of starch, which is white, but becomes blue by the action of almost any acid.†

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 starch, 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

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* 80 Ann. de Chim. 317. See also Thomson's Annals, v. 38, and Ann. de Chim. xc. 29.

† Colin and Gaultier de Claubry. 90 Ann. de Chim. 100.

ammonia; a considerable quantity of brown fetid thick oil; solid subcarbonate 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, a 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 reagents.*

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

Another ingredient, which was long supposed to be peculiar to animal products, viz. *albumen*, has been discovered in the emulsive seeds. In the almond, for instance, 30 per cent. have been found, of a substance precisely resembling animal curd.‡

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 oxy-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.

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* Nicholson's Journal, xviii. 34.

† See Proust on the Green Fecula of Vegetables, Nicholson's Journal, 8vo. iv. 273.

‡ Thomson's Annals, xii. 39.

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 alkalies; 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 alkalies 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 gunpowder.

7. 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.

Gay Lussac and Thenard have analysed, by their new process, the wood of oak and beech. The wood was taken from the most compact part of a log, reduced to a fine powder by a file, then sifted and washed in succession, with water and alcohol; and finely dried, before its admixture with oxymuriate of potash.

	Carbon.	Oxygen.	Hydrogen.
100 parts of Oak contain	52.53	41.78	5.69
——— Beech ———	51.45	42.73	5.82

In both, the oxygen and hydrogen are in the proportions required to form water, and there is no excess of oxygen to acidify any part of the carbon.

SECTION XIII.

Colouring Matter.

I. The colouring matter of vegetables presents a considerable variety in its relation to chemical agents, depending on the diversity 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 substances that afford it, and its fixation on wool, silk, or cotton, constitute the art of DYEING; 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 Memoirs;* to the works of Berthollet and Bancroft; and to a memoir of Thenard and Roard, in the 74th volume of Annales de Chimie.

III. Of the various colouring substances, used in the art of dyeing, some may be permanently attached to the dyed 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 durably attached by the mediation of what was formerly called a *mordaunt*, but has since been more properly termed, by the late 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 colouring matter is united with wool or cotton, are alumine, the oxide 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 tartaric acids. In dyeing, the most common method is to pass the substance to be dyed 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 dyed substances, are reducible to four simple ones, *viz.* blue, red, yellow, and black.

1. Indigo is the only substance used in dyeing 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. Aikins' Chemical Dictionary.

Indigo has been supposed to be a variety of fecula, but it differs from that principle in several important particulars. It is volatile, and may be sublimed at a temperature a little below that which is required for its decomposition.* 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 reddish brown hue. It is insoluble in alcohol, ether, and in fixed and volatile oils. Its

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* Gay Lussac, 74 Ann. de Chim. 191.

appropriate, and indeed only, solvent appears to be sulphuric acid. When thus dissolved, it is sometimes applied directly, in a diluted state, to the fabric, and dyes 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-oxydizement 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 dyed 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 permanent dye.

There appears, however, to be a certain stage of oxygenizement in indigo, which is essential to the existence of its blue colour, 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 decomposed. A thin layer of resinous matter appears, floating in the solution. If this be removed, and the solution, after evaporation to the consistence of honey, be re-dissolved, in hot water, filtered, 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, detonate and emit a purple light. If to a drachm or two of finely powdered indigo, we add an ounce measure of fuming nitrous acid, 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 oxymuriatic acid destroys its colour. Hence a solution of indigo in sulphuric acid has been recommended for measuring the strength of watery solutions of oxymuriatic acid gas; in order to regulate their application to the process of bleaching.

Alkalies do not act on indigo, unless it be previously reduced to that state of partial dis-oxygenation at which its green colour reappears. And the solution exists no longer, if oxygen be absorbed, and the blue colour restored.

The analysis of indigo by destructive distillation affords but little information respecting its nature. The products, usually obtained from vegetable substances, are evolved, along with a portion of ammonia. A copper-coloured sublimate, also, arises in fine needle-shaped crystals, possessed of peculiar properties. It has been called *Indigogene*.*

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 co-

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* Phil. Mag. xlvii. 415.

lours. Cochineal, though its colour is naturally crimson, is used for dyeing 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 exhibited 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 dyes 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 dye, 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 opaque 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 dyeing-woods; and from the infusion of cochineal, 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 Sir H. Davy, it is difficult to procure it in a state of perfect purity. Indeed, it has been doubted by several chemists, and especially by Chevreul and Pelletier,* whether tan has ever been obtained sufficiently pure, to entitle it to be considered as a distinct vegetable principle.

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 tan. When thus prepared, Sir H. 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 Sir H. 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. The purest kind of tan, we learn from the same authority, may be procured by the action of a small quantity of cold water on bruised grape seeds. 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.

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* See 87 Ann. de Chim. 103; and 47 Phil. Mag. 74.

Tan procured from galls has been analyzed by Berzelius, and found to consist of

Carbon	41.186
Oxygen	54.654
Hydrogen	4.186
	100.*

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 isinglass 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, not liable to putrefaction, that fits tan for the purpose of converting skins into leather.

Dr. Duncan, jun., who has made numerous experiments on tan, informs me, 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.†

In this country, a preference is universally given to oak bark for the purpose of tanning, but various other substances afford it, as appears from the following Table, drawn up by Sir H. Davy, from his own experiments:

Table of Numbers, exhibiting the Quantity of Tan afforded by 480*lbs. of different Barks, which express nearly their relative Values:*

	lb.
Average of entire bark of middle-sized Oak, cut in spring	29
——— of Spanish Chesnut	21
——— of Leicester Willow, large size	33
——— of Elm	13
——— of common Willow, large size	11
——— of Ash	16
——— of Beech	10
——— of Horse Chesnut	9

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* 24 Ann. de Chim. 322.

† See his paper on the union of Tan and Jelly, Nicholson's Journal, xxiv. 1.

	lb.
Average of entire bark of Sycamore	11
——— of Lombardy Poplar	15
——— of Birch	8
——— of Hazel	14
——— of Black Thorn	16
——— of Coppice Oak	32
——— of Oak cut in autumn	21
——— of Larch cut in ditto	8
White internal cortical layers of Oak Bark	72

The inner cortical layers of all barks Sir H. Davy found to contain the greatest proportion of tan. The quantity, also, is greatest at the time the buds begin to open, and is smallest in winter, and after a cold spring.

As a general average, four or five pounds of good oak bark are required to form a pound of leather. The operation is most perfect when performed slowly; for, if too rapidly effected, the outer surface of the skin is covered with a coat of leather, which defends the interior from change. In general, skins, by being completely tanned, increase in weight about one-third, the skin and the leather being each supposed dry.

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 platinum.

Green sulphate of iron effects no change in the solution of tan, but the red sulphate occasions a dark bluish 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 be oxygenized, by passing streams of oxymuriatic acid through its solution in water. Tan is capable, also, of uniting with oxide of lead, in different proportions, forming a tannate and sub-tannate of lead.*

Until within the last ten 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

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* Berzelius, 94 Ann. de Chim. 319.

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.*

To 100 grains of powdered charcoal, contained in a matrass, 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 reddish 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

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* See Philosophical Transactions for 1805 and 1806.

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[*] 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 oxymuriatic 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 hydrocarburet gases is 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 carbon
17.72 hydrogen

100.

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[*] Nicholson's Journal, ix 182.

[†] Cadet, Ann. de Chim. vol. xliv.

Gay Lussac and Thenard, by an improved method of analysis, have lately shown it to consist of

Carbon	81.784
Oxygen	5.544
Hydrogen	12.672
	100.

Of the hydrogen, part only is sufficient for the saturation of the oxygen; and besides this there are 11.916 in excess.

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 alkalies 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 a 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. The vegetable wax from Brazil, though it appears, from the experiments of Mr. Brande, to possess the principal characters of common wax, differs from it in some properties, and also from myrtle wax.[*]

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.[†]

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

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[*] Phil. Trans. 1811, p. 267.

[†] System of Chemistry, v. 95.

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 alkalies.

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. Mr. Donovan has also composed it by the action of strong nitric acid on an equal weight of sugar. In the residual matter, which is thick and tenacious, its presence is disguised by the sourness of the malic acid, but becomes sensible when this is neutralized by lime. This bitter principle, he conceives, may exist in unripe fruits, and may afford, accordingly as it is modified by vegetation, either sugar or vegetable acids.*

Another modification of the bitter principle has been extracted, by M. 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 drynesss, 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 alkalies, and composes crystallizable salts. Its compound of this substance with potash detonates when struck with a hammer, and inflames like gunpowder 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.

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* Phil. Trans. 1815.

SECTION XVII.

Narcotic Principle—Morphine.

Opium, and other vegetable products possessed of narcotic power, are composed of several of the vegetables principles that have already been enumerated Besides these, however, they contain a peculiar one, in which the narcotic virtue resides. Its preparation and chemical qualities have been investigated by Derosne, whose memoir is published in the 45th volume of the Annales de Chimie

I. To obtain the narcotic principle from opium by the process of Derosne, 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, oxygenized extract, and the narcotic principle. Boiling alcohol dissolves the resin and narcotic principle only; 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 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 deposits it on cooling. When heated in a spoon, it melts like wax.

5. It is soluble in acids, and precipitated by alkalies. 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.

Morphine or Morphia.

A more complete investigation of the narcotic principle has since been published by M. Sertuerner, of Eimbeck in Hanover, who has shown that the substance, described by Derosne, is a compound of a peculiar base (morphine) with an acid, existing, so far as is known, only in opium.

The following process is the one practised by Sertuerner for obtaining Morphine.* Rub together in a mortar eight ounces of powdered opium, two or three ounce measures of acetic acid, and a little cold distilled water; then add two or three pints of water, and strain the liquor. Add to it a solution of ammonia, and evaporate the liquor to one fourth. The morphine is precipitated, and may be separated by filtration. The liquid part is a compound of ammonia with the acid ingredient of opium.

Another method of separating morphine has been recommended by Robiquet.† A concentrated solution of a pound of opium in water is to be boiled with 10 or 12 drachms of carbonate of magnesia, during a quarter of an hour. A grayish deposit is formed in considerable quantity, which is to be washed first with cold water, and next with hot and weak alcohol, which takes up a small quantity of morphine and much colouring matter. It is afterwards washed with a little cold and concentrated alcohol, and then boiled with a sufficient quantity of the same fluid, which, at that temperature, dissolves morphine On cooling, it is deposited a little coloured; but by repeating the operation three or four times, it may be obtained colourless, and crystallized in regular parallelopipeds with oblique faces.

Pure morphine dissolves in boiling water only in small proportion, but is very soluble in heated alcohol and ether, and the solutions are intensely bitter. The watery and alcoholic solutions affect test papers like an alkali, and Robiquet thought this property most distinct in morphine prepared by the intervention of magnesia, which, from its complete destruction by burning, could not contain any proportion of that earth. It forms neutral salts with acids, and appears therefore to approach most nearly in its characters to an alkali, which it also resembles in decomposing the compounds of acids with metallic oxides.

Morphine fuses at a moderate heat, and resembles melted sulphur. On cooling from this state, it crystallizes. It unites with sulphur, but is incapable of forming soap with an oxidized oil.

Its effects on the human body are those of a violent poison. Three half grains, taken in succession with intervals of half an hour by the same person, produced violent vomiting and alarming faintings.

Another ingredient of opium is the *meconic acid*, which, according to Robiquet, is best obtained from the residuum of the magnesian salt, which is left undissolved by alcohol in the process for extracting morphine. This residue may be dissolved in very weak sulphuric acid, and to this solution muriate of barytes may be added. A rose-coloured precipitate falls, consisting of sulphate and meconate of barytes. This is to be digested a considerable time with hot sulphuric acid largely diluted. When the filtered liquor is sufficiently reduced by evaporation, the meconic acid shoots, even

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* Ann. de Chim. et Phys. v. 39.

† Ibid. 379.

before cooling, into coloured crystals. To obtain it pure, it must be washed with a small quantity of water, then dried, and sublimed at a gentle heat.

This acid is fusible at a temperature considerably above that of boiling water. It reddens vegetable blues, and is extremely soluble in alcohol and in water. Its distinguishing character is, that it produces an intensely red colour in solutions of iron oxidized to the maximum. Sertuerner did not find that when taken into the stomach, it is capable of producing any of the effects of opium.

The salt of Derosne, it appears from the experiments of Robiquet, is not a compound of morphine and meconic acid. The watery solution of opium, freed from morphine and meconic acid, contains another acid characterized by a different train of properties, which may be separated by a process somewhat circuitous.* This acid is not volatile, and has no peculiar action on the salts of iron With morphia it affords salts that are readily soluble in alcohol and in water Morphium and the salt of Derosne appear from the experiments of Robiquet to be both ingredients of opium, which are different and independent of each other.

Beside the ingredients which have already been mentioned, opium contains extract, which forms with morphine a compound almost insoluble in water, but very soluble in acids. A considerable proportion of resin, and a small quantity of caoutchouc, enter also into the composition of opium. These are entirely destitute of sedative properties, when received into the stomach. They remain after acting on opium first with water, and afterwards with muriatic acid. When the residue is digested with alcohol, the resinous matter is taken up; and from the remaining mass, which has resisted the action of alcohol, the caoutchouc may be extracted by rectified ether.

Tinctures of opium, it is observed by Sertuerner, should be prepared with pure alcohol, and kept in a place which is not very cold; for a low temperature precipitates morphine. The addition of a little acetic acid prevents this inconvenience.

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,

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* Ann. de Chim. et Phys. v. p. 285.

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 liquifies; and filter. The filtered liquor, as it cools, deposits 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 matrass, it sublimes, and is obtained in concentric circles, composed of numerous small points.

7 With alkalies, 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 carbureted hydrogen gas, with occasionally a small proportion of carbonic acid and sulphureted hydrogen. They are neither soluble in water nor in alcohol, and in the latter respect they differ from resin. 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 liquid bitumens had been derived, by a sort of natural distillation, from the solid; 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 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. Saussure found its specific gravity in its natural state to be .836, after one rectification .769, and after two .758; after which it could not be rendered lighter. 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, unless the alcohol be quite pure, and then the two fluids unite in any proportion.

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 Sir H. 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. When carefully rectified, Saussure did not find that it was at all altered by being kept three years in vials half full.

Its boiling point is 186° Fahrenheit. The density of its vapour is 2.833, air being 1. A mixture of this vapour with common air burns like carbureted hydrogen gas. By the detonation of its vapour with oxygen gas, Saussure determined the composition of naphtha to be

Carbon	87.21
Hydrogen	12.79
	100.

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* Linnæan Transactions, 1797.

It appears therefore to contain rather more carbon than is present in olefiant gas.*

PETROLEUM is considerably thicker than naphtha, and has a greasy feel. It is either wholly or in part transparent, and of a reddish 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 reddish or blackish brown colour. In chemical properties it resembles petroleum.

The solid bitumens are Maltha, Asphaltum, and Elastic Bitumen or Mineral Caoutchouc, besides 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 resembling naphtha, a portion of water impregnated with ammonia, and a quantity of carbureted hydrogen gas. It has been analyzed by Klaproth, whose accounts of it may be seen in the second volume of his "Contributions"

The appropriate solvent of asphaltum in 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 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.

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* Thomson's Annals, x. 118.

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 bitumenized, and exhibits, distinctly, the remains of the vegetables, from whose decay it has originated. It is brown, opaque, somewhat flexible and elastic, and nearly light enough to float on water. It burns with a clear flame, and with a bitumenous 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 carbureted hydrogen gas, which may be advantageously applied to burning in lamps. In the retort, a hard heavy charcoal remains called *coak*. It contains generally 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 with only 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 carbureted hydrogen gas, which, from its inferior density, cannot be advantageously burned in lamps.

In PEAT OR TURF, the remains of vegetable organization are generally very evident; and it consists, indeed, in a great measure, 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, approaches more in its characters to carbonic oxide than to carbureted hydrogen. In an excellent account of this substance, given 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 combustibility.

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 without flame or smoke. When long boiled in water, it yields a solution, which, on being concentrated and mixed with alcohol, becomes pitchy. By continued trituration, however, it is dissolved, with the exception of some earthy flocculi. The clear liquid, decanted and evaporated, yields a brownish saline mass; from which, by two successive evaporations and solutions, needle-shaped 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 acid. 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 alkalies, and affords with them crystallizable salts.

SECTION XX.

Of the Vegetable Principles of Asparagus, Elm-tree Gum, Elecampane, Mushrooms, Saffron and Cocculus Indicus.

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. *Asparagin.* 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 alkalies. 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.

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* Nicholson's Journal, xv. 242.

2. *Ulmin.* 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. Oxymuriatic acid produced a similar effect. The property, of producing a resin by the addition of a little oxygen, is peculiar to this substance, and sufficiently characteristic. Dr. Thomson has proposed for it the name of *Ulmin;* and he and Mr. Smithson have recently paid much attention to the investigation of its properties.* It appears to be a very common vegetable product, exuding from various trees, and existing, according to Berzelius, in the bark of most. When pure, it is tasteless; sparingly soluble in water and in alcohol; not precipitated by acids, gelatine or tan; and very soluble in alkaline carbonates, from which it is separated by acids and metallic salts.

3. *Inulin.* When the roots of the *inula helenium* or elecampane are boiled some time in water, the decoction, after standing some hours, deposits some white powder like starch, but differing in its chemical qualities. Rose, who was the first person that investigated its properties, found that it is insoluble in cold water, but that it readily dissolves in four times its weight of boiling water 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 may also be thrown down by alcohol. When placed on burning coals, it melts as readily as sugar; emits a similar smell; and is consumed, leaving a very small residuum of charcoal. 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.

Inulin has since been examined by M. Gaultier de Claubry, who has pointed out the following characters as discriminating it from fecula or starch. It is much more soluble than starch in hot water, with which it does not form a jelly, but is deposited on cooling in the form of a white powder. It dissolves, also, in four or five times its weight of water at 140° Fahrenheit, and the solution, when evaporated, becomes viscous, but not gelatinous. With iodine, it forms a greenish-yellow compound, which is spontaneously decomposed, in part at least, in a short space of time,

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* See his Annals of Philos. vols. 1 and 2; and Mr. Smithson's paper, Phil. Trans. 1813.

The inulin remains lightly coloured yellow, and retains a portion of iodine. Muriatic acid, as well as solutions of pure alkalies, render starch gelatinous, but dissolve inulin without giving any jelly. Concentrated sulphuric acid, which carbonizes starch, and is at the same time converted into sulphurous acid, dissolves inulin without any extrication of sulphurous acid; and the inulin may be precipitated by ammonia. These properties appear to be sufficiently characteristic to entitle inulin to be considered as a distinct vegetable substance. To obtain it in a state of purity, M. de Claubry recommends to boil the roots of elecampane in a sufficiently large quantity of water; to filter the liquor, and to evaporate it to the consistence of an extract, which is to be washed with cold water. From the washings, there falls a considerable quantity of inulin, which is to be gently dried, not however on filtering paper, as it adheres to this too firmly to be got off.*

4. *Fungin.* This substance has been extracted by Braconnot† from the fleshy part of mushrooms. It may be obtained by washing off the soluble ingredients with hot water, to which a little alkali has been added. There remains a white, insipid, soft, and but little elastic substance. It has a fleshy structure, and is in a high degree nutritious, and free from deleterious properties. When dry, it burns vividly, and emits an odour resembling that of bread. By destructive distillation, it yields ammonia, and not an acid like wood. It differs, also, from lignin, in being insoluble in alkaline solutions, except when they are heated and very strong. Pure ammonia dissolves a portion of it, but deposits it on exposure to air.

Weak sulphuric acid has no action on fungin. The concentrated acid chars it, and sulphurous and acetic acids are formed. Muriatic acid dissolves it slowly, and converts it into a gelatinous matter. When heated with diluted nitric acid, azotic gas is disengaged. In this property, and in the results of its putrefaction, as well as in yielding ammonia on distillation, it approaches very nearly to animal substances.

5. *Polychroite.* This name has been given, by Bouillon La Grange and Vogel, to the extract of saffron prepared with alcohol. It has a very intense yellow colour, a bitter taste, and an agreeable smell. It is soluble in water and in alcohol; and the solution, by exposure to light, gradually loses its colour, which is destroyed, also, by oxymuriatic acid. A few drops of sulphuric acid change the colour to a beautiful blue; and nitric acid, added in like manner, to green.

Polychroite unites with lime, potash, and barytes, and affords with those bases soluble compounds. Sulphate of iron precipitates it of a dark brown colour. By destructive distillation, it yields an acid liquor containing ammonia, and carbonic acid and carbureted hydrogen gases.

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* 94 Ann. de Chim. 200.

† 79 Ann. de Chim. 267.

6. *Picrotoxine.* This principle is the one which communicates to the *cocculus indicus* its deleterious properties. Boullay obtained it, from that seed, by the following process. The seeds, deprived of their pericarp, were boiled in a sufficient quantity of water; and to the decoction acetate of lead was added, as long as any precipitate was occasioned. The liquid was again filtered, and slowly evaporated to the consistence of an extract, which was dissolved in alcohol, and the solution evaporated to dryness. The dry mass consisted of picrotoxine, mixed with a little colouring matter, the latter of which was separated by a very small quantity of water, and the picrotoxine remained in small crystals. Its properties are the following:

1. It is white, and crystallizes in four-sided prisms. Its taste is disgustingly bitter. One hundred parts of boiling water dissolve four of picrotoxine, and one half separates on cooling. The solution does not affect vegetable blues.

2. Alcohol of the specific gravity .810 dissolves one third its weight of picrotoxine. The addition of a little water throws down a precipitate, which a larger quantity redissolves.

3. Sulphuric acid has no remarkable action on it. Nitric acid dissolves it, and affords a yellowish green solution When heat is applied, oxalic acid is formed. Acetic acid readily dissolves it, and it is precipitated by carbonate of potash. It is soluble, also, in weak solutions of the pure alkalies.

4 The results of its destructive distillation do not materially differ from those of other vegetable matter.

7. *Nicotin.* This is the principle in which reside the active properties of tobacco (nicotiana,) from the juice of which it may be extracted by the following process of Vauquelin[*] Evaporate the expressed juice to one fourth of its bulk, and pour off the fluid from the gritty matter which separates on cooling. Repeat this operation as often as any similar deposit takes place; and, when the fluid is so much inspissated that nothing farther can fall, digest it in alcohol. Distil off the alcohol, and concentrate the residual matter to dryness by a very gentle heat. Dissolve this again in alcohol, and again reduce it to a dry state. In this state, it still contains both acetic and malic acids; it must therefore be dissolved in water, and very cautiously saturated with potash. When this liquid is distilled to dryness, a solution of nicotin passes into the receiver. By dissolving the residual matter in water, and again distilling, repeating this process several times, the whole of the nicotin may be obtained in aqueous solution. This solution is colourless; has the peculiar smell of tobacco; and occasions violent sneezing. Its taste is acrid, and it possesses poisonous qualities. According to Vauquelin it is precipitated by tincture of galls, and it approaches most nearly in its properties to the volatile oils.

8. *Pollenin.* The pollen of tulips was ascertained by Professor

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[*] Ann. de Chim. lxxi. 139.

John to contain a peculiar substance, which was as first confounded with albumen; but to which he has since given the name of pollenin.* It is insoluble in alcohol, ether, water, oil of turpentine, naphtha, carbonated and pure alkalies; and when distilled yields ammonia and an acid liquor. It has a yellow colour, and is destitute of taste and smell. By exposure to the air, it putrefies, and acquires the smell of cheese. It is extremely combustible, and burns with great rapidity and flame, in consequence of which the pollen of the *lycopodium clavatum* has been often used in theatrical exhibitions to imitate lightning.

9 *Emetin.* There are three different genera of plants that are employed under the name of Ipecacuanha; but it is the root of a species of *callicocca*, that is directed by the Pharmacopœia of the London College. The cortical part of the root has been lately submitted to a skilful analysis by MM. Magendie and Pelletier, who have obtained from it about 14 per cent. of a peculiar matter, in which the emetic virtue of the root exclusively resides, and which they have therefore called *emetin*.†

To obtain emetin, powdered ipecacuanha is to be digested with sulphuric ether, which removes a portion of fatty matter. Alcohol is then to be digested on the remainder; the tincture to be evaporated by a water bath; and the dried matter dissolved in cold water, which separates the wax. It is next to be macerated on powdered carbonate of barytes, to remove the gallic acid; again dissolved in alcohol and evaporated once more. The emetic principle remains in the form of transparent scales of a reddish brown colour. It has scarcely any odour; has a slightly acrid and bitter, but not a nauseous taste; deliquesces in the atmosphere; is soluble in water and in alcohol in all proportions; and is incapable of being crystallized. It is decomposed by a heat exceeding that of boiling water, but gives no ammonia by distillation, which proves that nitrogen is not one of its elements. Gallic acid precipitates it from its solution; but the re-agent, that most powerfully affects it, is the sub-acetate of lead, which completely precipitates it from all its solutions. It appears, therefore, that emetin is a substance *sui generis*, possessing distinct and peculiar properties, which are the same from whichsoever of the plants, capable of affording it, it may have been obtained.

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* Thomson's Annals, vii. 49.

† Thomson's Annals, xi. 422.

CHAPTER XXI.

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. chap. vi. A more simple one, however, will sufficiently answer the purpose. It may consist of a large glass matrass, shaped like 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 aperture 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 receiving pipe of a gazometer, fig. 35, *b*. The matrass may then be half filled with a solution of sugar in a proper quantity of water, or with an infusion of malt with the addition of a little yeast. 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 deposits 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.

It has been a subject of controversy whether the alcohol, obtained by the distillation of wines, and of other fermented liquors, existed *ready formed* in those liquors, or has been actually *produced*, in consequence of a new arrangement of the elements of the fluid by the increase of temperature. The latter opinion was supported by Fabroni,[*] and had gained considerable currency, till the contrary was fully established by Mr. Brande,[†] in two memoirs; in the first of which it was shown, that the results of the distillation of wine are not affected by a variation of temperature equal to 20 degrees of Fahrenheit; and in the second, that alcohol may be separated from wine, without the intervention of heat.

When a solution of acetate of lead (sugar of lead), or of subacetate of lead (Goulard's Extract), is added to wine, a dense, insoluble precipitate is quickly formed, consisting of a compound of the metallic oxide, with the acid and extractive colouring matter of the wine. On filtering the fluid, we obtain a mixture of alcohol, water and a portion of the acid of the metallic salt; provided the latter has not been added in excess, in which case a part of the salt remains undecomposed. From this liquid, hot and dry subcarbonate of potash separates the water; and the alcohol floats at the top, forming a distinct stratum. By operating on artificial mixtures of alcohol and water, Mr. Brande found that when the alcohol is not less than sixteen per cent, the quantity indicated by the subcarbonate, was always within one half part in 100 of the real proportion contained in the mixture. The experiments may be repeated in glass tubes, from half an inch to two inches diameter, accurately graduated into 100 parts. Or, to ascertain in a more simple way, the quantity of alcohol in any wine, its acid may be saturated with potash; and a given measure then distilled with a gentle heat nearly to dryness; the deficient bulk of the distilled liquor being made up with distilled water. This mixture is to be shaken, and set aside for 24 hours. Its specific gravity will then show the quantity of alcohol which the wine contains, and which may be immediately seen by referring to Mr. Gilpin's Table, an abstract of which will be given presently.

Gay Lussac[‡] has lately recommended the substitution of very finely powdered litharge for the acetate of lead; and has added the important fact that wine distilled *in vacuo*, at the temperature of 60° Fahrenheit, affords alcohol: a convincing proof, if any had been required, that the alcohol is merely *separated*, and not *formed*, by distillation.

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[*] Ann. de Chim. xxx. 220.

[†] Phil. Trans. 1811, 1813.

[‡] 86 Ann. de Chim. 175.

From an extensive series of experiments, Mr. Brande has constructed the following

Table of the Quantity of Alcohol, of specific gravity .825 at 60° Faht. in various Wines, &c.

Kind of Wine.	100 Measures contain	Kind of Wine.	100 Measures contain
Port, average of 6	33.48	Vin de Grave	12.80
Ditto, highest	25.83	Frontignac	12.79
Ditto, lowest	21.40	Coti Roti	12.32
Madeira, highest	24.42	Roussillon	17.26
Ditto, lowest	19.34	Cape Madeira	18.11
Sherry, average of 4	17.92	Cape Muschat	18.25
Ditto, highest	19.83	Constantia	19.75
Ditto, lowest	13.25	Tent	13.30
Claret, average of 3	14.43	Sheraaz	15.52
Calcavella	18.10	Syracuse	15.28
Lisbon	18.94	Nice	14.63
Malaga	17.26	Tokay	9.88
Bucellas	18.49	Raisin Wine	25.77
Red Madeira	18.40	Grape Wine	18.11
Malmsey Madeira	16.40	Currant Wine	20.55
Marsala	25.87	Gooseberry Ditto	11.84
Ditto	17.26	Elder Wine	9.87
Red Champagne	11.30	Cider	9.87
White Ditto	12.80	Perry	9.87
Burgundy	14.53	Brown Stout	6.80
Ditto	11.95	Ale	8.88
White Hermitage	17.43	Brandy	53.39
Red Ditto	12.32	Rum	53.68
Hock	14.37	Hollands	51.60
Ditto	8.88		

Some doubt may, perhaps, be excited of the accuracy of this Table, by a reference to the comparative intoxicating effects of port wine and brandy, the latter of which certainly are more than double those of the former. But it is to be remembered, that, in wine, the alcohol is in a state of combination with other ingredients, which must necessarily diminish its activity on the animal system. Variations from the above proportions may, however, be expected to arise from the variable purity of the liquors, that may be the subjects of experiment. In Mr. Brande's analyses, great pains were taken to employ such as were perfectly unadulterated.

1. 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 ad-

dition 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; but it appears doubtful whether a little ether is not produced by its action. When the muriate 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. Gay Lussac recommends quicklime or barytes, in preference to muriate of lime; and Dubuc advises the use of dry alumine, by which he brought alcohol to the specific gravity .817, without any risk of forming ether by the process.*

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. 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 one 10th 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 Gravities of the Mixtures of Alcohol and Water.

Centesimal Parts of the Mixture.		SPECIFIC GRAVITIES According to Chaussier.	SPECIFIC GRAVITIES 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 80883
	65	0.9005	0 90941

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* 86 Ann. de Chim. 314.

† 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. The Tables of Mr. Gilpin are much too long to be inserted without abridgement in this work.

Centesimal Parts of the Mixture.		SPECIFIC GRAVITIES	
		According to Chaussier.	According to Gilpin. (last Table.)
Alcohol . .	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

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 9½°. 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 imflammable. 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.

Alcohol of the specific gravity .8152 at 50° Fahrenheit, gives a gas, the density of which is 1½ times that of the atmosphere. To become gaseous, alcohol absorbs 0.436, the caloric required to vaporize an equal weight of water.

6. It has never yet been congealed by any known method of producing artificial cold. Even when diluted with an equal weight of water, it requires a cold of 6° below 0 to congeal it. Mr. Hutton of Edinburgh, announced, indeed, several years ago,* that he had succeeded in congealing alcohol of the specific gravity .798, but neither a confirmation of the fact, nor the details of his process, have yet been published.

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 alkalies; but not with their carbonates. Of the class of salts with alkaline, earthy, and metallic bases, alcohol dissolves some copiously, others sparingly, and others not at all. The proportion, in which some of these are taken up, is stated in the following Table by Wenzel, the principal defect of which is the omission of the specific gravity of the alcohol 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

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* Nicholson's Journal, xxxiv. 166. See also Thomson's Annals, i. 221, and ii. 63, 471.

	Grains.
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 alcohol, 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	1	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 carbureted 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.

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* Nicholson's Journal, 4to. v. 7.

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	7.86
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. Alcohol was transmitted through a red-hot porcelain tube; by which operation it afforded water, and a quantity of gas, which readily admitted of analysis. By an elaborate set of experiments, alcohol, of specific gravity .792 at 68°, was proved to contain, per cent.

Carbon	51.98
Oxygen	34.32
Hydrogen	13.70
	100.

Beside the hydrogen, necessary to form water with the 34.32 parts of oxygen, there are 9.15 parts of hydrogen in excess. Now it is remarkable that this excess of hydrogen is to the carbon in alcohol (51.98) in the same proportions as the hydrogen is to the charcoal of olefiant gas; and we are, therefore, entitled to consider 100 parts of alcohol, of specific gravity .792, as constituted of $(9.15 + 51.98 =)$ 61.13 parts of olefiant gas and 38.87 of water; or two of olefiant gas, and one of water; or of two atoms of charcoal, three of hydrogen, and one of oxygen. In 1000 parts of alcohol, specific gravity .792, we have, therefore, the elements of 100 parts of olefiant gas, united with those of 63.6 water. But as this alcohol may still be supposed to contain 8.3 per cent. water, real alcohol is probably constituted of 100 parts of the elements of olefiant gas, and of 50 parts of water. Reducing these weights to volumes, and dividing the weight of the olefiant gas (100) by 0.978, its density; and the weight of the water (63.58) by the density of aqueous vapour, Gay Lussac finds that alcohol consists of

Olefiant Gas	102.5 volumes
Aqueous vapour	101.7 volumes

From which, he thinks, it may safely be inferred that alcohol is constituted of equal volumes of olefiant gas and of aqueous vapour, the condensation being half the sum of the volumes of those two bodies. This would give the specific gravity of vaporous alcohol 1.603, and by experiment it comes out 1.613, a coincidence as near as can reasonably be expected.

According to the analysis of sugar, made by the same philosopher in conjunction with Thenard, it consists of

Charcoal	42.47
Oxygen and hydrogen in the proportions required to form water . .	57.53

But if we suppose that sugar is composed of 40 parts by weight of charcoal and 60 of water, and convert these weights into volumes, it will then consist of

1 volume of charcoal in vapour,
1 volume of aqueous vapour,
or of
1 volume of charcoal in vapour,
1 volume of hydrogen,
½ a volume of oxygen.

But alcohol, it has been already stated, is constituted of

$$\text{1 vol. olefiant oil} = \left\{\begin{array}{l}\text{2 vols. vapour of charcoal,}\\ \text{2 vols. hydrogen,}\end{array}\right.$$

$$\text{1 vol. aqueous vapour} = \left\{\begin{array}{l}\text{1 vol. hydrogen,}\\ \tfrac{1}{2}\text{ vol. oxygen,}\end{array}\right.$$

or

$$\text{Alcohol} = \left\{\begin{array}{l}\text{2 vols. vapour of charcoal,}\\ \text{3 vols. hydrogen.}\\ \tfrac{1}{2}\text{ a volume of oxygen.}\end{array}\right.$$

And tripling the numbers representing the elements of sugar, in order to equalize the hydrogen of both,

$$\text{Sugar} = \left\{\begin{array}{l}\text{3 vols. vapour of charcoal,}\\ \text{3 vols. hydrogen,}\\ \text{3 half volumes of oxygen.}\end{array}\right.$$

Comparing, then, the composition of sugar with that of alcohol, it follows that to transform the former into the latter, we must remove

1 vol. of the vapour of charcoal,
1 vol. of oxygen gas,

which, by combining, form 1 volume of carbonic acid. Reducing these volumes to weights, 100 pounds of sugar should afford 51.34 of alcohol and 48.66 carbonic acid.*

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 received 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 cupful of water or mercury. The condensible vapour is thus confined; while the gases that are produced are allowed to escape. The receiver and adopter 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.

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* Gay Lussac, 95 Ann. de Chim. 311.

If, when the ether ceases to be formed, the receiver be removed, and the heat still continued, sulphurous acid is produced 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 adid; and, after each addition, cool the materials, by setting the retort in a vessel of cold water. Distil the liquor 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 redistilled, 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.[*]

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 oxygenized 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 oxymuriate of tin. The distilled liquid is to be rectified by

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[*] Nicholson's Journal, xviii. 144.

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. *Chloric ether* may be formed by causing a current of olefiant gas, and another of chlorine, to meet in a glass balloon, taking care that the first mentioned gas is somewhat in excess. An oily fluid condenses, which may be purified by first washing it with a little water, and then distilling it from fused muriate of lime. It is limpid and colourless, and its smell and taste are both rather agreeable. Its specific gravity is 1.2201; its boiling point 152° Fahrenheit; its vapour, at 49° Fahrenheit, supports a column of mercury 24.66 inches high; and the specific gravity of this vapour is 3.4434, air being 1. It burns with a green flame, giving out a smell of muriatic acid and much soot. It is composed of 100 chlorine + 38.88 olefiant gas; and hence it may be inferred to consist of one atom of chlorine and two atoms of olefiant gas.*

V. *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.†

VI. *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.‡

VII. *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 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

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* Thomson, Werner, Trans. vol. i.; and Robiquet and Colin, Ann. de Chim. et Phys. i. and ii.

† See Boullay, Ann. de Chim. lxii. 192.

‡ Nicholson's Journal, viii. 143.

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 has been observed by Girard, that ether escapes through a capillary tube with much greater velocity than water or alcohol, the relative times, for equal quantities of each fluid, being 101 seconds for ether, 349 for water, and 856 for alcohol. The comparative heights, to which these three fluids rose in the same capillary tube, were found to be nearly 6 for ether, 9 for alcohol, and 13 for water.[†]

3. Ether 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 de St. Fond, 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 de St. Fond's Travels in England, chap. i.

4. 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, from a capillary tube, on a thermometer bulb filled with water, 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 72½° Fahrenheit, fill the space of a cubic foot.[‡] According to Gay Lussac, ether, of specific gravity 0.7365 at temperature 50° Fahrenheit, produces a gas, the density of which is to that of air as 2.35 to 1.

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[*] Ann. de Chim. lxix. 45. See also Thenard on the Action of Vegetable Acids on Alcohol, Mem. d'Arcueil, ii. 5, or 37 Phil. Mag. 216.

[†] 6 Ann. de Chim. et Phys. 239.

[‡] Saussure, jun.

5. A mixture of sulphuric and muriatic ethers evaporates instantaneously, and produces a degree of cold considerably below 0 of Fahrenheit.

6. Ether assumes a solid form, by reducing its temperature to — 46° Fahrenheit.

7. 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.

8. Ether does not dissolve the fixed alkalies, but it combines with ammonia.

9. 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.

10. 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 ether, which may be expelled through the pipe and set on fire. It burns with a beautiful deep blue flame.

11. 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 two and one third 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 pure oxymuriatic 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 piece 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.

12. Sulphuric ether was first observed by M. Planche to undergo a spontaneous change when kept in a vessel not entirely full,

and frequently opened and exposed to the light. By this exposure ether becomes acid in consequence of the production of vinegar, and loses somewhat of its sweet odour and its volatility.[*] This observation has been confirmed by Gay Lussac,[†] who found that ether, which had been very attentively purified, so that its boiling point did not exceed 96° Fahrenheit, nor its density 0.7119, and which had no action on turnsole, acquired this last property by keeping, and at the same time became specifically heavier and less volatile. When a part of the ether thus altered was distilled off, the residue evidently contained both acetic and sulphuric ether, and a peculiar kind of oil, which Gay Lussac thinks it probable exists in all ether, since that fluid, even when recently and skilfully prepared, leaves an evident spot on the glass on which a few drops are put to evaporate.

13. During his investigations on flame, Sir H. Davy discovered that when a piece of fine platinum wire is heated and placed over the surface of ether in an open glass, a pale lambent flame plays around it, the wire becoming red, and even white hot, and frequently inflaming the ether. At the same time, peculiarly pungent fumes arise, the production of which takes place at all temperatures, from a heat rather above the boiling point of mercury, until the ether is inflamed. These vapours are extremely acrid and pungent; they resemble chlorine in smell; and affect the eyes in a manner similar to the compound of chlorine and nitrogen. Their nature has been examined by Mr Faraday[‡]; but under great disadvantages from the smallness of the quantity in which they are produced. By passing considerable quantities of a mixture of atmospheric air and ether through a heated glass tube, containing platinum in wire and leaf, he obtained a clear and colourless liquor, of a slightly acid taste and strong irritating smell. It reddened litmus paper, as did, also, its vapour. When heated it was quickly dissipated, leaving on the capsule a slight coally mark. It united to ammonia, and formed a neutral salt, which, by careful evaporation, might be obtained solid, but was volatile, even at temperatures below boiling water, producing a peculiar fetid smell. It united with potash, and formed a salt, from which the acid was expelled by heat alone. The acid solution expelled carbonic acid from all the alkaline carbonates; and salts were obtained, from which the acid was again expelled by all the stronger acids. Oxygen, hydrogen, and charcoal (the last apparently in very great proportion) are the elements of which this new acid is composed; but Mr. Faraday could not obtain enough to determine their proportion.

14. 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.[§] M. Saussure, however, has lately submitted ether to analysis with somewhat different results. By following the same

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[*] Ann. de Chim. et Phys. iii. 213.

[†] Ibid. ii. 98.

[‡] Journal of Science, iii. 77.

[§] Nicholson's Journal, 4to. v. 205, n.

processes as those which have been already described, and, also, by the rapid combustion of ether with oxygen gas, he found that 100 parts of sulphuric ether, of specific gravity 0.7155 at 68° Fahrenheit, contain

Carbon	67.98
Oxygen	17.62
Hydrogen	14.40
	100.

The excess of hydrogen, above what is necessary to form water with 17.62 parts of oxygen, is 12.07 parts, which, when added to the carbon (12.07 × 67.98) give 80.05 for the olefiant gas in 100 parts of ether. The remainder 19.95 parts are water. Ether, therefore, is constituted of 5 atoms of olefiant gas, and 1 atom of water; or of 6 atoms of hydrogen, 5 of charcoal, and 1 of oxygen.

To understand the conversion of alcohol into olefiant gas or ether, it is necessary to compare the proportion of their elements.

Alcohol consists of 100 parts of olefiant gas + 50 water.
Ether ——— 100 parts ditto + 25 water.

If then, to alcohol, we add a proportion of sulphuric acid sufficient to take away the whole of the water, we obtain only olefiant gas. But if we use no more sulphuric acid, than is sufficient to abstract half the water contained in alcohol, we then obtain ether. It must not, however, be supposed that, in practice, we are ever able to effect these conversions without loss; for a certain proportion of the alcohol is decomposed, by the too energetic action of the acid, into its ultimate elements, especially towards the close of the process; and beside ether or olefiant gas (whichever it may be our object to prepare) we obtain sulphurous and carbonic acids, and a charry residue. It is nevertheless true that the sulphuric acid is efficient in the formation of ether, merely by abstracting water; and that nothing, by this process, is transferred from the acid to the alcohol; for if it be stopped in time, the whole of the acid may be recovered.

The complete accuracy of the results obtained by Saussure has been called in question by Gay Lussac,* chiefly on theoretical grounds. Reducing these results from weights to volumes, Gay Lussac finds that ether, according to Saussure, should consist of

Olefiant gas	102.49 volumes
Aqueous vapour	40.

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* Ann. de Chim. xcv.

But the density of the vapour of ether was found by experiment to be 2.581, and supposing it to be constituted of 2 volumes of olefiant gas and 1 volume of aqueous vapour, and the condensation of these to be two-thirds, its density should be 2.586, an agreement so near that the hypothetical view is probably the true one. Ether, then, will be constituted of

Olefiant gas	100.00	by weight
Water	31.95	
or		
Olefiant gas	2 volumes	
Aqueous vapour	1 volume	

And since alcohol consists of

Olefiant gas	2 volumes
Aqueous vapour	2 volumes

it follows that to change alcohol into ether, all that is necessary is to take away one volume of water, or, by weight, half the water which alcohol contains. Therefore 131.95 parts by weight of alcohol, if the conversion could be made without loss, should give 115.975 parts of ether; a proportion which, as has already been stated, can never be obtained in practice.

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 termed 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 combination a larger proportion of oxygen derived from the metallic oxide, from which acetous acid is generally distilled, when converted 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 Darracq. The last mentioned chemist succeeded in converting distilled into radical vinegar, under circumstances where no farther oxygenation could possibly be effected, viz. by repeated distillation from dry muriate of lime; which can only act by abstracting water. Both terms, however, may be retained for the sake of brevity; the *acetous 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 ropy filaments appear; and, after several days, it acquires 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 indispensable condition; whereas the vinous fermentation may be performed in close vessels, or at least in vessels which only allow egress to the elastic fluids that are produced.

Common vinegar may be purified, by submitting it to distillation in a glass retort. The best malt vinegar, unadulterated by sulphuric acid or colouring, has a specific gravity of 1.0204. When distilled, the first eighth part is of sp. gr. 0.99712, and contains so much acid, that a fluid ounce dissolves from 4.5 to 5 grains of precipitated carbonate of lime. The subsequent six eighths are of sp. gr. 1.0023, and a fluid ounce decomposes 8.12 grains of carbonate of lime. A similar quantity, of sp. gr. 1.007, decomposes from 15 to 16 grains of precipitated carbonate of lime, or 13.8 grains of marble.* By distillation, vinegar can only be imperfectly purified. The distilled liquor always contains an extractive matter, which Darracq considers 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 quantity 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 possible to remove entirely; so that the acid, thus prepared, may be employed for all the purposes of vinegar.

A process, for the decoloration of all kinds of vinegar, has been proposed by Figuer. The agent he employs is animal charcoal, which may be prepared by calcining the most compact beef or mutton bones in a crucible, to which a cover must be luted, having a small aperture, to allow the escape of the gases, and of the

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* Philips on the London Pharm. p. 7.

other volatile substances. Towards the close of the calcination, when no more flame issues, this aperture must be closed, and the heat raised for half an hour To a wine quart of cold vinegar, an ounce and half of this charcoal, finely powdered, is to be added, and occasionally stirred. In 24 hours, the vinegar begins to lose its colour, and, in three or four days, is entirely deprived of it. It is then to be filtered through paper, and it will be found (if the charcoal has been well prepared) to retain its acidity, without having acquired any unpleasant flavour. By reducing the quantity of charcoal to one half, the change is still effected, but more slowly.

Acetous acid unites with alkalies, earths, and metallic oxides.

When potash, saturated with this acid, is evaporated to dryness, the salt assumes a black colour. On being re-dissolved, however, and again evaporated, the salt is obtained white, and, when fused 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 decomposed; carbonic acid and carbureted 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 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 MM. 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 quali-

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* Annales de Chimie, lxiii. 267.

ties of ether, and like that fluid has the power of decomposing the nitro-muriate of gold. MM. 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.* 1063,) 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 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. M. 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 liquify 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.

Gay Lussac and Thenard, and Berzelius, have recently analyzed acetic acid; the two first by the combustion of acetate of barytes, of known composition, with hyper-oxymuriate of potash. Their results are as follow. One hundred grains of acetic acid consist of

	Carbon.	Oxygen.	Hydrogen.
According to Gay Lussac	50.224	44.147	5.629
——— Berzelius	46.8	46.9	6.3

The proportions obtained by Gay Lussac and Thenard may be stated also as follows:

Carbon	50.224
Oxygen and hydrogen in the same proportions as in water	46.911
Excess of oxygen	2.865
	100.

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* Annales de Chimie, lxviii. 88; or Nicholson's Journal, xxv. 155.

The acetic acid enters, like vinegar, into combination with alkalies, 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 carbureted 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. Berzelius found it to consist of

Acetic acid	36.95
Soda	22.94
Water	40.11
	100.

Or exclusively of water,

Acid	61.689	100
Soda	38.311	61.1
	100.	

ACETATE OF AMMONIA derives its only importance from having been long 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 Berzelius, it is composed of

Acid	64.218	100.
Lime	35.782	55.74
	100.	

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. Chenevix finds that it gives pure pyro-acetic ether, of the specific gravity, 0.845, coloured by a little empyreumatic oil. Gay Lussac and Thenard state its composition to be

Acid	43.17
Base	56.83
	100.

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 dyeing 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. Gay Lussac,* however, has found that it has the remarkable quality of being decomposed by heat and of depositing alumine, which it re-dissolves on cooling. The effect takes place, even in vessels hermetically sealed, and when the solution has an excess of acid. It appears to bear some analogy to the coagulation of animal albumen.

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 been made by 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 alkalies. 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

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* 74 Ann. de Chim. 93; and 6 Ann. de Chim. et Phys. 201.

† Ann de Chim. vol. lxix; or Nicholson's Journal, vol. xxvi.

distilled, the metal was found in a metallic state; but zinc and manganese were left in the state of oxides.

The pyro-acetic spirit, obtained from the 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 0.864. 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 XXII.

ANIMAL SUBSTANCES.

The products of vegetable and of animal life, though they agree in many of their 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 had till lately 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 method of analysis, so successfully applied, by Gay Lussac and Thenard, to the products of the vegetable kingdom, has been extended, also, to animal substances;* and, in the history of each, the proportion of its ultimate elements will be stated, chiefly on their authority, or on that of Berard or Prout. Animal substances, they observe, contain much more carbon than those derived from the vegetable world; in all of them, the hydrogen is in excess with relation to their oxygen; and lastly, the greater this excess, the more azote they contain. It is remarkable, moreover, that this azote, and the excess of hydrogen, are very nearly in the proportions required to constitute ammonia.

Animal matters, then, such as fibrin, albumen, gelatine, &c. are composed of charcoal; of hydrogen and oxygen, in the proportions required to form water; and of hydrogen and azote, in the proportions necessary to constitute ammonia. They hold, therefore, among animal matters, the same rank that sugar, gum, lignin, &c. possess among vegetable substances. The animal acids, again, consist, probably, of carbon, oxygen, hydrogen, and azote, in such proportions, that the oxygen and azote are in excess relatively to the hydrogen. And the animal oils, on the other hand, will in all probability be shown to contain more hydrogen, than is sufficient to convert their oxygen into water, and their azote into ammonia. Thus animal substances will be divided, like vegetable ones, into three great classes, relatively to the quantities of hydrogen, oxygen, and azote, which they contain.

The primary animal compounds are not very numerous; the

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* Ann. de Chim. xcvi. 53; and Berard, Ann. de Chim. et Phys. v. 290, where the process is fully described. See also Mr. Porrett's remarks, Phil. Trans. 1815, p. 225; and Dr. Prout's in the Medico-Chirurg. Trans. viii. 530.

following list comprehending, perhaps, the whole of those which are sufficiently well characterized.

1. Gelatine.
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. Berzelius, indeed, in his View of Animal Chemistry, p. 50, considers gelatine as a *product* of the operation of boiling; and denies its existence in any one fluid of the body. This opinion, however, requires further evidence in its favour. 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. M. D'Arcet prepares gelatine from bones, not by boiling, but by dissolving out the earthy matter by means of diluted muriatic acid. The gelatine remains in a solid state, preserving the form of the bone. To purify it from small remains of acid and fat, it is plunged for an instant into boiling water, then exposed to a current of cold water, and quickly dried, in which state it is unalterable by keeping.* 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.

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* Phil. Mag. xlvi. 17.

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 concentrations 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 oxymuriatic 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 oxymuriatic 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 oxymuriatic acid at common temperatures; and still more abundantly when heated. In alkaline solutions they disappear, and muriatic salts are formed.†

5. Gelatine is soluble in pure liquid alkalies. 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 alkalies, 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

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* Nicholson's Journal, xi. and xiv. † Thenard, Mémoires d'Arcueil, ii.

‡ Hatchett, Philosophical Transactions, 1800.

gold causes a small quantity of a dense precipitate, from a solution containing one 50th of gelatine, but not from more dilute solutions.

7. One of the most active precipitants of jelly is tan; and Dr. Bostock finds the extract of rhatania, digested in hot water, and filtered after it becomes cold, to be a convenient form for keeping that test. When the proportion of gelatine to water is so small, as to compose only one 5000th part of the solution, a considerable precipitate is produced by an infusion of galls (prepared by maceration 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 putrifying; 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 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 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. Gelatine has been analysed by Guy Lussac and Thenard, who employed the chlorate of potash for its decomposition. One hundred parts were found to contain

Carbon	47.881
Oxygen	27.207
Hydrogen	7.914
Azote	16.998
	100.

In this analysis, there are 4.204 parts of hydrogen, beside what is sufficient to saturate the oxygen.

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.*"

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 an 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, amount to 4½ 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, 4½ uncoagulable matter, and only 15½ of pure albumen. At a temperature below that required for its coagulation, Dr. Bostock finds that it may be dried, and redissolved in water.†

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 one 1000th its weight of albumen, was rendered perceptibly opaque 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 ascertained, was not affected by muriate of mercury, or by infusion of galls; but was copiously precipitated by Goulard's extract of lead. He

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[*] Philosophical Transactions, 1800.

[†] Medico-Chir. Trans. ii. 169.

considers it as a peculiar fluid to which he has given the name of *mucus*. Dr. Marcet, who finds it to be an ingredient of several morbid fluids, has proposed to call it *muco-extractive matter*.*

Albumen, which has been coagulated by heat, though perfectly insoluble in water, unless by long boiling aided by a Papin's digester, 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 alkalies 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 alkalies, even, as Thenard 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 one 1000th 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 one 2000th of albumen.

Solution of corrosive sublimate, however, does not 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 10½ grains of albumen.

Nitro-muriate of tin precipitates albumen, but less actively than

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* Medico-Chir. Trans. ii. 377.

† Thenard, Ann. de Chim. lxvii. 321.

‡ Philosophical Transactions, 1809.

the foregoing salt. Water, holding one 500th 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 one 1000th 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 2½ parts of solid extract in 100, is added to a liquor, of which albumen forms only one 1000th 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. The precipitate by tan from diluted albumen, Dr. Bostock observes, is incoherent, subsides very slowly, and can scarcely be separated by a filtre; whereas the precipitate from solution of jelly of the same strength is a hard dense substance, which almost immediately separates from the fluid, and may be collected in a distinct mass.

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 soluble in dilute acids, and precipitable by the some 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.

7. Albumen contains a portion of sulphur in intimate combination, which gives it the property of blackening silver. This effect is often observed to be produced by eggs on spoons of that metal; and blood, evaporated in silver vessels, stains them with sulphuret of silver.

Many theories have 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 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

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* System of Chemistry, v. 439.

† Philosophical Transactions, 1809.

follow that the *rapid* abstaction 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 74½ of coal, of which 11¼ 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 ascertained, also, by Sir E. Home, that albumen is coagulated by galvanic arrangements of too low a power to affect even the most delicate electrometer; and hence he has proposed albuminous fluids as tests of the presence of small quantities of electricity.[*]

Albumen was found by Gay Lussac and Thenard, to consist of

Carbon	52.883
Oxygen	23.872
Hydrogen	7.540
Azote	15.705
	100.

Beside, therefore, the hydrogen required to saturate the oxygen, there are 4.285 parts in excess.

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 defi-

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[*] Philosophical Transactions, 1809. [†] Phil. Trans. 1800.

nite meaning. Jelly and mucus he considers 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 liquid, 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 Berzelius, on the other hand, seems scarcely to admit any fluid entitled to the general name of *mucus;* and finds that its chemical characters vary in different parts of the body, according to the purpose which it is intended to fulfil in the animal economy.‡

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, 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 method of determining, exactly, the proportion of mucus in any compound fluid. One great obstacle to all attempts of this kind is, that mucus, beside 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. For 1000 grains of saliva, he obtained by evaporation 120 grains of dry residuum, of which twenty grains were saline matter. The proportion of

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* Nicholson's Journal, xi. and xiv.

† Annales de Chimie, lxvii.

‡ View of Animal Chemistry, p. 58.

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 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.

Mucus, as appears from Dr. Marcet's experiments, beside forming an ingredient of several healthy secretions, exists in some morbid fluids, particularly in that effused in all the forms of dropsy.

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 the 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.

The following history of the chemical properties of fibrin is derived chiefly from a memoir of Berzelius.

1. Fibrin is insoluble in cold water; but water, after being boiled upon it for some hours, is found to have acquired a milky hue, and, on the addition of infusion of tan, affords a precipitate of white and distinct flocculi, which do not cohere like those produced by gelatine. The liquid, obtained by boiling fibrin, does not gelatinate, to whatever degree it may be concentrated, but gives a white, dry, hard, and friable residue, which is soluble in cold water. By long boiling in water, fibrin loses its property of softening and dissolving in acetic acid.

2. Alcohol, of the specific gravity .810, converts fibrin into a kind of adipocirous matter, which is soluble in alcohol, and is precipitated by the addition of water. When alcohol, which has been digested on fibrin, is evaporated, a fatty residue is left, which did not pre-exist in the fibrin. By the action of ether, fibrin is converted into an *adipocire*, similar to the preceding, but in much greater abundance, and distinguished by a much more disagreeable odour.

3. In concentrated acetic acid, fibrin immediately becomes soft, transparent, and, with the assistance of heat, is converted into a tremulous jelly. By the addition of warm water, this jelly is completely dissolved, with the evolution of a small quantity of azotic gas. The solution is colourless, and of a mawkish and slightly acid taste. By sufficient evaporation, the gelatinous substance is reproduced, which, when completely desiccated, is a transparent mass, insoluble in water without the addition of fresh acetic acid. The solution gives a white precipitate with ferro-prussiate of potash, and with pure alkali; but a slight excess of alkali re-dissolves it. Sulphuric, nitric, and muriatic acids also occasion a precipitate, which consists of fibrin and the acid that has been employed. When laid on a filter and washed, a certain quantity of this acid is carried off by the water, and the remaining substance is soluble in pure water.

4. In weak muriatic acid, fibrin shrinks, and gives out a little azotic gas, but scarcely any portion is dissolved, even by boiling. Concentrated muriatic acid, when boiled on fibrin, decomposes it, and produces a red or violet coloured solution. Fibrin, that has been digested with weak muriatic acid, is hard and shrivelled. By repeatedly washing with water, it is at length converted into a gelatinous mass, which is perfectly soluble in tepid water. The solution reddens litmus paper, and yields a precipitate with acids, as well as with alkalies.

5. Concentrated sulphuric acid decomposes and carbonizes fibrin. The same acid, diluted with six times its weight of water, and digested with fibrin, acquires a red colour, but dissolves scarcely any thing. The undissolved portion is a compound of fibrin with an excess of sulphuric acid; and when this excess is removed by water, a neutral combination is obtained, which is soluble in water, and possesses the same characters, as the neutral compound of fibrin and muriatic acid.

6. Nitric acid of the specific gravity 1.25 disengages at first azotic gas from fibrin, pure and unmixed with nitrous gas. By continuing the digestion 24 hours, the fibrin is converted into a pulverulent mass, of a pale citron colour, which, when placed on a filter and washed with a large quantity of water, becomes of a deep orange colour. This yellow substance was discovered by Fourcroy and Vauquelin, who obtained it by treating muscular flesh with nitric acid, and who gave it the name of yellow acid. Berzelius has ascertained that it is a combination of nitric and malic acids with fibrin, which is in some degree altered by the process.

7. In caustic fixed alkali, fibrin increases in bulk, and, at length, is completely dissolved. The solution is yellow with a shade of green; and is decomposed by acids; but the precipitated fibrin seems to have undergone some change, for it is not, as before, soluble in acetic acid. The compound of fibrin and alkali has not any analogy with soap, which Fourcroy asserts that it resembles.

8. Fibrin has been analyzed by Gay Lussac and Thenard, and found to consist of

Carbon	53.360
Oxygen	19.685
Hydrogen	7.021
Azote	19.934
	100.

Besides the oxygen and hydrogen in the proportions required to form water, there is an excess of 4.337 parts of hydrogen per cent.

SECTION V.

Urea.

1. **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, not however in a state of complete purity.

II. 1. Urea, thus obtained, 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. Berzelius, by processes which he has not described, obtained urea quite free from colour, and forming distinct prismatic crystals like nitre.* Even in this state, he observes, it is still obstinately combined with lactic acid, lactate of ammonia, and the peculiar animal matter, which always accompanies the lactates. It is this animal matter, which gives the urine its colour.

Dr. Prout was induced by the observation of Berzelius to attempt the preparation of pure urea, and succeeded by the following process.

Fresh urine was carefully evaporated to the consistence of syrup, and to this, when quite cold, pure concentrated nitric acid was added by degrees, till the whole became a dark-coloured crystallized mass, which was slightly washed with cold water, and suffered to drain. To this mass, a pretty strong solution of sub-carbonate of potash or soda was added, till the whole became neutral. The solution was carefully concentrated by evaporation, and set aside, in order that the nitre might separate by crystallization. The liquor drained from these crystals was an impure solution of urea, which was mixed with a sufficient quantity of animal charcoal to form it into a thin paste. To this, after remaining a few hours, water was added to separate the urea, and the colourless solution was evaporated at a very gentle heat to dryness. From the dry mass, boiling alcohol separated the urea, and left the nitre and most of the saline substances behind, and from the alcoholic solution the urea was obtained pure by evaporation and crystallization, the solution in alcohol being repeated if the crystals were coloured.

UREA thus purified most frequently assumes the form of a four-sided prism. Its crystals are transparent and colourless, and have a slight pearly lustre. It leaves a sensation of coldness on the tongue like nitre. Its smell is faint and peculiar, but not resinous. It does not affect the colours of litmus or turmeric. On exposure to the air it slightly deliquesces, but does not seem to be decomposed. At a strong heat it melts, and is partly decomposed, and partly sublimes unaltered. The specific gravity of its crystals is about 1.350. They are soluble in an equal weight of water at 60° Fahrenheit, and to any extent in boiling water. Alcohol at 60° Fahrenheit, dissolves about one fifth of its weight, and at 212° more than its weight.

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. Oxalic acid produces the same effect; but in neither of these compounds are the acids neutralized. The nitrate of urea, Dr. Prout finds to consist of

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* View of Animal Chemistry, 8vo. p. 101.

Nitric acid	47.37	= 1 atom
Urea	52.63	= 2 atoms
	100.	

3. The concentrated solution of impure 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 carbureted 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 when heated 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 carbonate 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 sup-

posing 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, ochtohedral 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, urea appears most readily to undergo 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 with oxide of copper, Dr. Prout has given the following as the proportions of its elements. One hundred parts consist of

Oxygen	26.66	= 1 atom or $\frac{1}{2}$ volume
Nitrogen	46.66	= 1 atom or 1 volume
Carbon	19.99	= 1 atom or 1 volume
Hydrogen	6.66	= 2 atoms or 2 volumes.

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 22 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 evaporate by a gentle heat. At a certain point of concentration, a green sediment falls down, which, after being separated from the liquid part, and washed, affords what has been considered as resin. Berzelius, however, (as will be more fully stated in the section on bile,) denies that it is a true 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 alkalies it combines, and forms a compound, which has been compared to soap. From these it is precipitated unchanged by acids.

4. When farther oxygenized, by adding oxymuriatic acid to bile, the resinous portion has its properties considerably altered; it acquires the colour and consistence of tallow; melts at 140°; 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, castor, &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 allowed to cool. It concretes into a solid mass, which is to be dissolved in water, clarified by white of eggs, filtered, and again evaporated 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.

Gay Lussac and Thenard have obtained by their analysis, the following results, which correspond, almost exactly, with those of Berzelius.

Carbon	38.825
Oxygen	53.834
Hydrogen	7.341
	100.

The oxygen and hydrogen are in the proportions necessary to form water; and the carbon is in excess.

3. When exposed to heat, it melts and burns with the same appearances as common 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 vegetable 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. Chevreul has, also, obtained similar crystals, which when drained, then pressed, and dissolved in hot alcohol, gave a solution that by slow evaporation afforded perfectly white crystals. In its properties, diabetic sugar he found to approach most nearly to the sugar obtained from grapes;[*] and Dr. Prout, by analysis, finds its composition precisely similar to that 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 (called by Chevreul[‡] *cetine*) 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, forming a true soap. 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. From the solution by potash, Chevreul separated, by adding an acid, a substance, which he terms *cetic acid*. It is a white solid, fusible at nearly the same point as spermaceti, but which does not, on cooling, crystallize in plates. It is insoluble in water, but much more soluble in alcohol than spermaceti, and is susceptible of union with various bases, with which it forms salts or soaps.[§]

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 sub-

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[*] 95 Ann. de Chim. 319.

[†] Med. Chir. Trans. viii. 537.

[‡] Ann. de Chim. et Phys. vii. 155.

[§] Ann. de Chim. xcv. 17.

stance, thus obtained, may be bleached, by exposure to chlorine gas. From the experiments of Chevreul and of Gay Lussac,* the fatty matter thus obtained appears to be separated, rather than formed, by the processes which have been described. Their inferences, however, are not admitted by Dr. Thomson.†

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 one-fourth or one-fifth 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 alkalies act on this substance, as on wax and spermaceti, forming with it a soluble soap. 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 membranous 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 alkalies and forms soap. It is apt to become rancid by keeping, owing to the formation of an acid, most probably by the oxygenation 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 *oxygenated fat.*

Melted fat dissolves both sulphur and phosphorus. It unites, also, with several metallic oxides, and forms compounds, which have nearly a solid consistence.

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* Ann. de Chim. et Phys. iv. 71.

† Annals, xii. 41.

Stearin, Elaïn, &c.

It has been shown by the experiments of Chevreul, which have been confirmed by those of Braconnot,[*] that fat is not homogeneous, but composed of two distinct substances. When hog's lard is heated with alcohol, the fluid on cooling deposits white crystalline needles, which may be purified by again disolving them in hot alcohol, and allowing them to crystallize a second time. To the solid thus obtained, Chevreul has given the name of *stearin*, from στεαρ tallow. It is white, brittle, and free from taste and smell, and in appearance resembles wax. Its point of fusion varies from 109° to 120° Fahrenheit, according to the source from which it has been obtained. It is soluble in heated alcohol; and is convertible into soap by being treated with alkalies.

When the alcoholic solution of fat, after having deposited all its stearin, is submitted to distillation; there remains an oil, which is fluid at 59° Fahrenheit, and is called by Chevreul *elaïn* (from ελαιον, oil.) It has generally both colour and smell, but these are not essential to it, and depend on the source from which it has been obtained. It is convertible into soap with alkalies.

Braconnot separated these two component principles from each other, by simply pressing fat between folds of blotting paper, which imbibes only the elaïn, and again gives it out on being moistened with water and submitted to pressure. The proportion of the two ingredients differs considerably in different varieties of fat. Stearin being the cause of its hardness is, of course, most abundant in fat of firmest consistence.

When hog's lard is made into a soap with potash, and this soap is put into water, it is partly dissolved, and partly deposited in pearl-coloured scales. These scales consist of potash united with a peculiar acid, which is separated by adding a due quantity of muriatic acid, and floats on the surface of the liquor. Chevreul at first gave it the name of *margarine* (from μαργαριτης, a pearl,) but afterwards proposed that of *margaritic acid*. It is tasteless, but reddens litmus, is fusible at 134°, and on cooling shoots into brilliant white needles; floats on water, and is insoluble in it; but is soluble to great extent in alcohol. It unites with potash in two proportions, viz. that of 100 acid to 8.80 potash, and of 100 acid to 17.77 potash. It is, also, capable of uniting with other salifiable bases.

That portion of the soap of hog's lard, which remains dissolved in water, is a compound of potash with a different acid, mixed however with some proportion of the margaritic. To separate this acid, the soap was decomposed by tartaric acid; the *oleic acid* thus obtained, was again saturated with potash, and the compound again decomposed by tartaric acid. After two or three repetitions of

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[*] Ann. de Chim. tom. lxxxviii. xciii. xciv. xcv.; and Ann. de Chim. et Phys. vol. ii. &c.

this process, an oily fluid was obtained, destitute of smell and colour; of the specific gravity .899; and remaining fluid till cooled to 35°, or, in some of its varieties, to 43°. This acid does not unite with water, but is very soluble in alcohol. It unites also, with salifiable bases, and forms a variety of salts or soaps, the precise composition of which has been stated by Chevreul.*

A very remarkable experiment has been performed by Berard, the result of which has been the production of a substance resembling fat from bodies in a gaseous state. It consisted in mixing together one volume of carbonic acid, 10 volumes of carbureted hydrogen, and 20 volumes of hydrogen, and passing the mixture through a red-hot porcelain tube. He obtained a substance in small white crystals; lighter than water, soluble in alcohol, and fusible by heat into a fluid resembling a fixed oil.† Dobereiner is said, also, to have obtained a similar product by igniting a mixture of coal gas and aqueous vapour.

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. It may be obtained; by dissolving a calculus of this kind (the external characters of which will be hereafter described,) reduced to fine powder, in solution of potash; decomposing the clear solution by muriatic acid *added in excess;* and washing the precipitate with a large quantity of distilled water. The precipitate may be drained, and dried at 212°, a temperature sufficient to deprive it entirely of water.

1. Uric acid, when pure, is destitute of colour, taste, and smell; it dissolves in 1720 parts of cold water, or 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 alkalies, 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,

* Ann. de Chim. xciv. 263.

† Thomson's Annals, xii. 41.

however, of uric acid with alkalies, 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 prussic acid is formed. On evaporation to dryness, a bright red or carmine coloured mass remains, consisting, as appears from the analysis of Dr. Prout, of ammonia, united with a new acid recently discovered by him, to which he has given the name of *purpuric acid*, from the beautiful purple colour exhibited by its compounds.* 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 deposits 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. By submitting uric acid to destructive distillation along with oxide of copper, Gay Lussac determined that the carbon is to the azote which it contains, in volume, as 2 to 1, as is also the case in cyanogen.† It has been shown, also, by Berard, that in uric acid, the hydrogen is to the oxygen in a greater proportion than in water, contrary to what has been established with respect to vegetable acids.‡ Dr. Prout has, also, analyzed uric acid by the same process as that of Gay Lussac, and finds it to be composed of

Hydrogen	2.857	= 1 atom or 1 volume
Carbon	34.286	= 2 atoms or 2 volumes
Oxygen	22.857	= 1 atom or ½ volume
Azote	40.	= 1 atom or 1 volume
	100.	

II. There is a substance well known to physicians, as a deposit from the urine at certain stages of fever, at the close of attacks of gout, 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 the rose. This acid, he observes,

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* Thomson's Annals, xii. 68.

† 96 Ann. de Chim. 53.

‡ Ann. de Chim. et Phys. v. 295.

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. The experiments of Proust were confirmed and extended first by Vauquelin and afterwards by Vogel.* The latter chemist finds that concentrated sulphuric acid converts rosacic acid first into a deep red powder, and afterwards into a white insoluble substance which has all the properties of uric acid. Nitric acid effects the same change. It appears, therefore, that the rosacic and uric acids differ but little from each other, and that the transition is easily made from the former to the latter

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 alkalies 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; from which it may be separated 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 alkalies 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. Fourcroy, indeed, supposed 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.† But Berzelius contends that it is a distinct acid, and that it exists, either free or united with soda, and in all animal fluids.‡

V. The *saccholactic* or *mucous acid* (the latter of which names is considered by Berzelius as improper) is formed by pouring on powdered sugar of milk, in a stoppered retort, four times it weight

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* 96 Ann de Chim. 306.

† Nicholson's Journal, x. 264.

‡ Thomson's Annals, ii. 201, note. See also his investigation of the lactic acid, in Phil. Mag. xli. 241.

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 liquid 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 alkalies 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 crystallizable, 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 deposits 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. Gay Lussac and Thenard have determined its composition to be

Carbon	33.69
Oxygen	62.69
Hydrogen	3.62
	100.

There are, therefore, 36 parts of oxygen more than sufficient to saturate the hydrogen.

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 alkalies; 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 separated, and washed with boiling water. The water entirely dissolves it, and becomes concrete on cooling.

The sebacic acid, thus procured, has a white colour; is without smell; has a slightly acid taste, and reddens infusion of litmus. 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 alkalies 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 higher temperature than benzoic acid, which, in several particulars, it resembles. Berzelius, indeed, considers it as merely benzoic acid, impregnated with other products of the distillation by which it has been obtained.

VII. The *prussic acid* is formed, chiefly during the decomposition of animal substances, at high temperatures; or rather, as Gay Lussac has rendered probable, a *cyanide* of *potash* is formed, which becomes a prussiate of potash, when acted upon by water and an acid conjointly, in the manner already explained in the section on cyanogen. 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 ten or twelve parts of water; allow it to soak for 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 boiling 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 properties have already been described. (Chap. xix. 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, known in the druggists' shops by the name of *red precipitate*, with four ounces of finely-powdered prussian blue; and boil the mixture with twelve ounces of water in a glass vessel, shaking frequently. Filter the solution, which is a prussiate of mercury, 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 does not, like most other acids, redden vegetable blue colours, though it combines with alkaline and earthy bases.

Prussic acid has the following properties:

1. It is capable of assuming a gaseous form, and may be collected in that state over mercury, by heating, in a retort, the crystallized ferro-prussiate of potash with dilute sulphuric acid. This gas is absorbed by alcohol, and forms a permanent combination with it; but its solution in water undergoes spontaneous decomposition, becomes yellow in a few months, and deposits charcoal. The gas has, also, a constant tendency to escape from its watery solution.

2. Prussic acid gas is inflammable, and is instantly decomposed by contact with chlorine gas. A new compound is formed of chlorine and cyanogen, which was first described by Berthollet, and afterwards examined by Gay Lussac. From the latter it has received the name of *chloro-cyanic acid*.* It appears to be constituted of 1 volume of the vapour of charcoal, ½ a volume of azote, and ½ a volume of chlorine, condensed into one volume.

3. When received into the lungs of small animals, prussic acid gas is speedily fatal; and its watery solution, when taken into the stomach, proves almost instantly poisonous.†

4. In its pure state, it becomes a liquid at ordinary temperatures, as Gay Lussac has shown.‡ To obtain it in this state, prussic acid gas was disengaged from prussiate of mercury by muriatic acid,

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* Thomson's Annals, viii. 47.

† Robert, 92 Ann de Chim. 52.

‡ Ann. de Chim. lxxvii.

and after passing through two bottles containing dry muriate of lime and chalk, was condensed in a third, which was surrounded by a freezing mixture.

5. Liquid prussic acid, thus procured, is a limpid and colourless fluid. Its taste is at first cool, but soon becomes hot and acrid. Though rectified from chalk, it still reddens litmus paper slightly. Its specific gravity at 45° Fahrenheit is .7058. It is highly volatile, and boils at 79° Fahrenheit; at 68° it supports a column of mercury at very nearly 15 inches; and it increases, five fold, the bulk of any gas with which it is mixed. It congeals at the temperature produced by snow and salt, and liquefies at 5° Fahrenheit. A drop of it placed on paper becomes solid instantly, because the cold, produced by the evaporation of one portion, reduces the temperature of the remainder below its freezing point.

The specific gravity of prussic acid vapour is to that of common air as 0.9476 to 1; but by calculations founded on its composition and the condensation of its elements, it may be stated at 0.9360. At a temperature between 86° and 95° Fahrenheit, it forms with oxygen gas a mixture which detonates on passing an electric spark. A quantity equal to 100 measures condense 125 measures of oxygen, and there result 100 measures of carbonic acid and 50 measures of nitrogen. But as the carbonic acid contains only its own volume of oxygen, there remain 25 measures of the latter gas which must have been converted into water by 50 measures of hydrogen existing in the prussic acid vapour. From these and other facts, Gay Lussac infers that it is composed of one volume of the vapour of charcoal, half a volume of hydrogen, and half a volume of nitrogen, condensed into one volume, or by weight of

Carbon	44.39
Azote	51.71
Hydrogen	3.90
	100.*

The half volume of nitrogen and one volume of vapour of charcoal, existing in the vapour of prussic acid, constitute a peculiar base already described in the first volume under the name of *cyanogen.* This base, like chlorine and iodine, is acidified by hydrogen, and the proper appellation for the prussic acid Gay Lussac conceives to be *hydro-cyanic acid*, and for its compounds *hydrocyanates.* The equivalent of oxygen being 10, that of the hydrocyanic acid is deduced by the same philosopher to be 33.846, and subtracting from this number the equivalent of hydrogen, there remains 32.520 for that of cyanogen.

From these facts, there appears to be a remarkable analogy between cyanogen and chlorine and iodine; and the resemblance to

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* Thomson's Annals, vii. 357, or Ann. de Chim. xcv. 136.

chlorine extends also to their respective compounds with hydrogen; for as muriatic acid is decomposed by the black oxide of manganese, so is hydro-cyanic vapour by peroxide of copper, which gives up oxygen to the hydrogen of the acid, and sets at liberty the elements of cyanogen, the nitrogen in a free state, and the carbon in the state of carbonic acid.

6. Prussic acid does not appear to have a strong affinity for alkalies; 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 alkalies and earths are decomposed by exposure to carbonic acid, even when highly diluted, as in atmospheric air. It readily combines, however, with pure alkalies; and forms crystallizable salts, which have an excess of alkali, are soluble in alcohol; and are incapable of forming prussian blue with salts containing the peroxide of iron. But these simple prussiates, by combination with protoxide of iron, acquire all the characters of triple prussiates.

An ingenious view of the nature of the triple prussiates has been taken by Mr. Porrett, in the Philosophical Transactions for 1814. He considers them, not as *triple* salts, but as *binary* compounds of the respective bases with an acid, which is constituted of the elements of prussic acid, united with the protoxide of iron. That this oxide is really an element of the acid, and not a base, he has rendered highly probable by determining, that when prussiate of soda in solution is exposed to the agency of galvanic electricity, the black oxide of iron is carried along with the elements of the prussic acid, to the positive pole; whereas, if it had existed in the salt as a base, it would have appeared at the negative pole.

This compound acid he obtained in a state of watery solution, by adding, to a solution of triple prussiate of barytes, just sulphuric acid enough to precipitate the barytic earth. Its characters he describes as follows:

It has a pale lemon yellow colour; has no smell; is decomposed by a gentle heat, or by exposure to a strong light; in which case prussic acid is formed, and white triple prussiate of iron, which, by absorbing oxygen, becomes prussian blue. With alkalies, earths, and oxides, it forms, directly, the salts called triple prussiates. It displaces the acetic acid from all its combinations; and also detaches, from other acids, those bases, with which it is susceptible of forming compounds, that are insoluble in acids. As it is decomposed by heat, this acid can never be obtained by distillation. In that case, prussic acid and triple prussiate of iron are always formed.

This view of the subject explains why the iron, in triple prussiates, is not discovered by the most delicate tests; for it can no more be affected by them; than sulphur can be indicated by its appropriate tests, when existing in sulphuric acid.

In the nomenclature of prussic acid and its compounds, Mr. Porrett has not proposed any change; but for the peculiar acid, which it affords when combined with protoxide of iron, he suggests the name of *ferrureted chyazic acid;* and its compounds he terms *ferrureted chyazates.* It would, perhaps, have been preferable to have designated these bodies by the names *ferro-prussic acid*, and *ferro-prussiates;* at least these names have the advantage of greater brevity; and, for that reason, I shall employ them.

Some doubts have been thrown upon these conclusions of Mr. Porrett, by the researches of Gay Lussac, which have rendered it probable that some of the prussiates (that of mercury for instance) are in fact compounds of *cyanogen* with a metal. Under this view; they bear a strict analogy to the compounds of chlorine, and may be more properly termed *cyanides.* There undoubtedly, however, exists a class of compounds of prussic acid with bases, to which the name of prussiates (or *hydro-cyanates*, as Gay Lussac proposes) is strictly due. They are all alkaline; are decomposed by the weakest acids; and, in many respects, are analogous to the *hydro-sulphurets.* That of ammonia is the most remarkable. It crystallizes in cubes; is extremely volatile; and is decomposed with great facility. When to these compounds we add oxide of iron, more powerful acids are required to decompose them; but this, as Gay Lussac observes, is what happens also with other triple salts. Alumine for example, when united with sulphuric acid and potash, forms a more energetic combination than when combined with that acid only. Without, therefore, disputing the facts of Mr. Porrett, he is disposed to withhold his assent from the opinion that prussic acid, by combining with oxide of iron, composes a new acid.

Beside the protoxide of iron, Mr. Porrett finds that there are other substances, which are capable of forming, with the elements of prussic acid, peculiar acids, characterized by a distinct train of properties. Sulphur is one of these bodies.

Sulphureted chyazic or sulphureted prussic acid was first obtained by Mr. Porrett, by decomposing prussian blue with sulphuret of potash. To a heated solution of one part of the latter, three or four parts of prussian blue in powder are to be added at distant intervals; and the liquid, which contains the compound in question, along with several neutral salts, is to be filtered: Or a solution of prussiate of mercury may be decomposed by hydrogureted sulphuret of potash: Or, lastly, a mixture of animal charcoal and sulphuret of potash may be calcined, in a red heat, for some hours, and the product lixiviated. The clear liquor (however obtained) is to be supersaturated with sulphuric acid; and kept, for a short time, at nearly the boiling point. A little finely powdered oxide of manganese, added when cold, turns the liquid a beautiful crimson. A solution of two parts sulphate of copper, and three of green sulphate of iron, is to be added, till this colour disappears. A white precipitate falls, which is a compound of protoxide of copper with sulphureted prussic acid. The acid may then be transferred to potash, by boiling the precipitate with that alkali; and it may be obtained separate, by distilling the liquid with sulphuric acid.

The sulphureted chyazic or prussic acid is generally colourless, but sometimes pinkish; it has the specific gravity 1.022; and it has a smell, resembling that of strong acetic acid. It dissolves sulphur when boiling, but lets the greater part fall again on cooling. It forms, with nitrate of silver and pronitrate of mercury, white precipitates. With alkaline and earthy bases, it composes a distinct genus of neutral salts. It appears to be constituted of 26.39 sulphur + 14.23 prussic acid.

VIII. The *zoonic acid* has been shown by Thenard to be merely the acetous, holding some animal matter in solution. The *formic* acid, or acid of ants, was submitted to a course of experiments by Fourcroy and Vauquelin, who inferred that it is merely a mixture of acetic and malic acids. This conclusion was opposed by the experiments of Suersen, who endeavoured to prove that formic is really a peculiar acid; but its identity with the acetic has since been confirmed.* Gehlen, however, has lately published a series of experiments, the object of which is to prove that the formic is really a peculiar acid. Its smell and taste differ, he alleges, entirely from those of acetic acid. When sufficiently cooled, it becomes solid, but does not crystallize. Its specific gravity is 1.1168; when diluted with an equal weight of water, it becomes 1.060; and with twice its weight, 1.0296; in all which respects it differs from acetic acid.†

The formic acid is recognized, also, as a peculiar compound by Berzelius, who, from the proportion of the ingredients of formate of lead, deduces its equivalent to be 46.8, that of oxygen being 10. By analysis, he obtained as the ingredients of formic acid,

Hydrogen	2.807
Carbon	32.970
Oxygen	64.223
	100.

Reducing these proportions to volumes, we have the following comparative table of the acetic and formic acids:‡

	Oxygen.	Carbon.	Hydrogen.
Acetic acid	3	4	6
Formic acid	3	2	2

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* Ann. de Chim. lxiv. 48.

† Thomson's Annals, v. 24.

‡ Thomson's Annals, iv. 105.

CHAPTER XXIII.

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 entirely 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 connexion 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 3½ minutes, and to be completed in seven. Fourcroy states that, during coagulation, caloric is evolved; and this fact appeared to be established, also, by the experiments of Dr. Gordon, who found the coagulating part of a quantity of blood warmer than the rest, by from 6° to 12° Fahrenheit.* Subsequent experiments by Dr. John Davy† have, however, rendered the fact extremely questionable, and have led to the suggestion of some sources of fallacy in Dr. Gordon's investigation.

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 very variable, but on the average is about 1029. 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 slightly opaque liquor, of a saline taste and a peculiar odour, oozes from it, which is called the *serocity*. This fluid has generally been considered as holding gelatine in solution; but Dr. Bostock has found reason to doubt the accuracy of the opinion; in which conclusion he is supported by Brande and Berzelius.

Mr. Brande coagulated two fluid ounces of serum, and digested the coagulum, cut into slices, in four fluid ounces of distilled water, which was afterward separated by means of a filter. The liquid, when evaporated to half an ounce, gelatinized on cooling, and was precipitated by an infusion of tan; but this effect might equally well be produced by the presence of albumen; and decisive evidence of the presence of the latter substance was obtained, by placing some of the fluid in the Voltaic circuit, when a rapid coagulation of albumen took place round the negative wire. After having coagulated, by Galvanic electricity, all the albumen of a portion of serum, the residuary liquor gave no indications of gelatine. Mr. Brande, therefore, infers, that the serosity consists of albumen, in combination with a large proportion of alkali.‡

The serosity, according to Berzelius, contains no sulphuric acid, and only a vestige of the phosphoric; but it consists of water, of pure soda holding albumen in solution, of muriates of soda and potash, of lactate of soda, and an animal matter, which always accompanies the lactate.§ The solid contents of the serosity, Dr. Bostock finds to vary from one 46th to one 70th of its weight; but on an average, they may be stated at one 50th. It has been a subject of controversy,‖ which of the mineral alkalies exists in serum in an uncombined form. Dr. Pearson maintains that it is potash; but Drs Bostock, Berzelius, aud Marcet, allege that it is soda; and the evidence preponderates in favour of the latter opinion.

When serum is evaporated, at a heat below that required for its coagulation, it yields a yellowish semi-transparent mass, resembling amber, that splits to pieces in drying, and amounts to about

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[*] Thomson's Annals, iv. 339.

[†] Journal of Science, &c. ii. 246.

[‡] Phil. Trans. 1812.

[§] Thomson's Annals, ii. 201.

[‖] See Medico-Chir. Trans. ii. 356, 368; and Nicholson's Journal, vols. xxx. xxxi. xxxiii.

95 grains from 1000 of serum. This substance softens in water, and becomes gelatinous; and about 36 per cent. of its weight are dissolved, and may be passed through a filter. The insoluble part is albumen; and much of this exists, also, in the filtered liquor, beside the neutral salts, which have already been mentioned.

The mineral acids coagulate serum so completely, that no albumen remains in the serosity. The insoluble compounds, which are produced, exactly resemble those of the same acids with fibrin; and the action of alcohol is the same in both cases. Hence Berzelius contends, that there is very little difference between albumen and fibrin. The only character of distinction between them appears to be, that albumen does not coagulate spontaneously, but requires a high temperature; and from this circumstance, it is less rapidly soluble than fibrin in acetic acid.

The serum of human blood is composed, according to Berzelius, of

Water		905.0
Albumen		80.0
Substances soluble in alcohol, viz.		
Muriates of potash and soda	6	10.0
Lactate of soda and animal matter	4	
Substances soluble in water only:		
Soda, phosphate of soda, and a little animal matter		4.1
Loss		0.9
		1000.

This analysis agrees very remarkably with one of Dr. Marcet, who obtained the following ingredients. The substance termed by him *muco-extractive matter*, is doubtless impure lactate of soda; and the sulphate of potash, and earthy phosphates, were probably formed by the combustion.

A thousand parts of human serum contain,

Water	900.00
Albumen	86.80
Muriates of potash and soda	6.60
Muco-extractive matter	4.00
Subcarbonate of soda	1.65
Sulphate of potash	0.35
Earthy phosphates	0.60
	1000.

Vogel considers sulphur as another constituent of serum; for he finds that when serum is kept for some days, at the temperature of between 75° and 90° Fahrenheit, a gas exhales from it, which renders legible characters written on paper with acetate of lead.* This experiment was found to answer with the bile and urine; but it can scarcely be regarded as a proof, that the blood contains sulphur *as such*, or in any state but that of intimate combination. The same chemist has endeavoured to establish the presence of carbonic acid in blood when recently drawn† from a vein.

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.

Fibrin, as it is contained in the blood, is held in a state of solution; aud 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 microscope. They appear to dissolve readily in water, and tinge it with their own peculiar colour; but Dr. Young finds that the globule remains entire, though colourless. They are soluble in alkalies, acids, and alcohol, but not in the serum. The watery liquid turns syrup of violets green; and, after some time, deposits a flocculent precipitate, doubtless from the coagulation of albumen, the presence of which is indicated, also, by the effect of boiling the solution. It seems 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 four 1000ths of the weight

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* Ann. de Chim. vol. lxxxvii.

† 93 Ann. de Chim. 71.

of solid matter, and composed, according to Fourcroy and Vauquelin, chiefly of sub-phosphate of iron.

It has been contended that the red colour of the blood is owing to the iron which it contains, but this opinion has been rendered extremely questionable by the experiments of Mr. Brande. Berzelius, indeed, had found that a quantity of oxide of iron exists in the ashes of the colouring mattter; while none, or at least an infinitely small portion, is afforded by the other ingredients of blood. He cut the crassamentum into thin slices, and placed them on blotting paper; and after this had ceased to draw out any moisture, he dried the slices. Four hundred grains of the dried substance left, after incineration, 5 grains of ashes, which were composed (supposing 100 to have been operated on) of

Oxide of iron	50.0
Sub-phosphate of iron	7.5
Phosphate of lime with a small quantity of magnesia	6.0
Pure lime	20.0
Carbonic acid and loss	16.5
	100.

The iron in colouring matter is not, Berzelius admits, in such a state, as to be capable of being detected by the nicest tests of that metal, until the composition of the colouring matter is destroyed by combustion. Nor is there any truth in the synthetic proof alleged by Fourcroy, that *subphosphate* of iron dissolves in albumen, and imparts to it a bright red colour, resembling that of blood.

To procure the colouring matter of blood in a detached state, Mr. Brande employed venous blood, stirred during its coagulation. The fibrin is thus removed; and the colouring matter is diffused through the serum, from which it gradually subsides in a very concentrated form. It retains, indeed, some serum; but this does not interfere with the effects of various agents upon the colouring principle.

The aqueous solution has a bright red colour, and is not very prone to putrefaction. It is not altered by any temperature below 190° or 200° Fahrenheit; but, at higher temperatures, it becomes turbid, and deposits a pale brown sediment. If the fluid be poured upon a filtre, water passes through colourless; so that exposure to heat destroys the solubility of colouring matter.

Diluted sulphuric and muriatic acids, and acetic, oxalic, citric, and tartaric acids, dissolve the colouring matter, and extract it from the crassamentum. The solution has more or less of a scarlet hue, according to the acid employed; but it is always green, when viewed, in narrow tubes, by transmitted light. Nitric acid destroys the red colour, and converts it to a brown.

The pure and carbonated alkalies dissolve the red matter, the colour of which remains unimpaired. The solution in liquid ammonia approaches nearest to scarlet. When these solutions are supersaturated with muriatic or sulphuric acids, the liquid acquires a colour, similar to the original solution of the colouring matter by those acids.

Alumine cannot be brought to form a permanent red compound with the colouring principle of the blood. But when the colouring matter is left to stand a few days, in contact with a solution of the crystallized muriate of tin, a bright red powder precipitates, which is a combination of the colouring matter with oxide of tin. When kept in water, it sustains no change of colour; but when dried by exposure to air, it loses its brilliant tint, and assumes a dull red hue.

The most effectual mordaunts, which Mr. Brande discovered for the colouring matter, are solutions of mercury (especially nitrate) and corrosive sublimate. When either of those salts was added to a watery solution of the colouring matter, a deep red compound was deposited, and the liquid became colourless. Woollen cloth, also, first impregnated in these solutions, and then dipped into the aqueous solution of colouring matter, acquired a permanent red dye, unalterable by washing with soap.

It appears, therefore, that the colouring principle of the blood is an animal substance of a peculiar nature, susceptible, like the colouring matter from vegetables, of uniting with bases, and admitting, probably, of important use in the art of dyeing. On examining the colouring matter, distinctly from the crassamentum, Mr. Brande did not discover a greater proportion of iron, than in the other principles of blood; and the theory may, therefore, be considered as completely set aside, which accounts for the red colour of the blood by the presence of iron.

The conclusions of Mr. Brande have been lately confirmed by Vauquelin, who recommends the following method of obtaining, in a separate form, the colouring matter of the blood.

Let the coagulum of blood, well drained upon a hair sieve, be digested in four times its weight of sulphuric acid diluted with a double proportion of water, at the temperature of 160° Fahrenheit, for five or six hours. Filter the liquor while yet hot, and wash the residuum with a quantity of hot water, equal in weight to the acid which has been employed. Concentrate the liquor to half its bulk; then add pure ammonia, till there remains only a slight excess of acid. After having agitated the liquor, allow it to stand, and a purple sediment will be deposited. This sediment is to be washed with distilled water, till the washings cease to precipitate the nitrate of barytes. It may then be drained on filtering paper, and dried at a very gentle heat.

When dry, it is destitute of taste and smell. It resembles jet in colour, fracture, and lustre. When moistened with water, it assumes a wine red colour, but does not dissolve in that fluid. In acid and alkaline liquids, it readily dissolves, and communicates to them a purple colour. Its acid solutions are not precipitated by gallic acid or by prussiate of potash, thus proving the absence of iron Infusion of galls, however, precipitates it without any change of colour. It is soluble in diluted nitric acid, without being discoloured, nor is this effect produced by nitrate of silver; but it is completely discoloured by nitrate of lead, which throws down a brown precipitate.*

In opposition to these experiments, it is still maintained by Berzelius, that the colouring matter of the blood contains iron, not indeed discoverable by re-agents, but decisively proved to exist in its ashes. In every respect except in containing that metal, the colouring matter of the blood agrees with fibrin and albumen, and he seems disposed to believe that its colour, though not depending on the presence merely of an oxide of iron, may be produced by a compound of which that oxide is an essential part.†

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. Priestley, 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 coolur, inclining to purple. In this state it arrives 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

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* Ann. de Chim. et Phys. i. 9, or Thomson's Ann. viii. 230.

† Ann. de Chim. et Phys. v. 42.

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 8½ *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 by an herbivorous animal, 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 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.

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* Philosophical Transactions, 1808.

† Ibid, 1809.

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.

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. A fact, however 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 temperature. 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.*

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.

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* Nicholson's Journal, xvii. 215.

The blood is subservient to several 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; it does not, however, exist in the blood in the state of sub-phosphate of lime or bone earth; but appears to be produced, from the *ultimate* elements of blood, on the very spot where its presence is required.* The muscles, which are fixed to the bones, and which, acting as levers, enable us to change our situation at pleasure, are referrible 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, 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

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* Berzelius's Animal Chemistry, p. 19. † Fourcroy, Systême, 4to. v. 268.

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:

Water	80
Coagulated albumen . . .	8
Mucus	11
Saline substances	1
	100.

Berzelius has lately published a more exact analysis of saliva.† Its constituents are

Water	992.9
A peculiar animal matter . . .	2.9
Mucus	1 4
Alkaline muriates	1.7
Lactate of soda and animal matter .	0.9
Pure soda	0.2
	1000.

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

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* Nicholson's Journal, xiv. 147.

† Thomson's Annals, iii. 25.

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. Vauquelin always found phosphoric acid in the gastric juice of herbivorous animals, whilst, on the other hand, that of man and carnivorous animals seldom gave any visible traces of free acid or alkali.

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 some time 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, 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 the 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 memoirs on

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[*] Philosophical Transactions, 1809.

[†] Mémoires d'Arcueil, vol. i.

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 deposits 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, phosphate of lime, and sulphate of soda. Traces, also, are discovered of oxide of iron.

The uncombined soda in bile does not exceed one 200th 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. 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 sulphureted 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 sulphureted 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 alkalies, 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-bladders 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. Sulphureted 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.

Berzelius denies the presence of resin in bile,* and asserts that it is not possible to repeat the analysis of that fluid, by the processes which Thenard has described. The substance, he alleges, which, in bile, resembles resin, is precipitable by acids; and the precipitate is a compound of the acid employed with the green colouring matter of bile. When we use sulphuric acid with heat, a green liquid is obtained resembling a resin; and after saturating the acid with carbonate of barytes, the green matter is soluble in water, to which it imparts its own colour and bitterness. This is the characteristic ingredient of bile, which Berzelius calls *biliary matter.* He finds bile composed of

Water	907.4
Biliary matter	80.0
Mucus of the gall bladder	3.0
Alkalies and salts common to all animal fluids	9.6
	1000.

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 a mere trace 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 one 11th 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

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* 71 Ann. de Chim. 220.

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 alkalies, 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 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 alkalies, 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 alkalies, and the fixed and volatile oils, effect their solution. One of their

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[*] These are the numbers given by Thenard (Mémoires 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.

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 from 88 to 94 *per cent.* of adipocire, and six or twelve of a colouring substance. A few were greenish on the outside, and yellow in the 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.

It was, therefore, concluded by 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.

Chevreul, however, has given to the crystalline matter of biliary calculi, the name of *cholesterine*, because it differs both from spermaceti and from adipocire in not being capable of affording a soap with alkalies. He has found, also, that when heated with an equal weight of strong nitric acid, a peculiar acid is formed, which he terms the *cholesteric.* This acid separates on cooling in the form of a yellow substance. It is scarcely soluble in water, but dissolves in alcohol, and may be crystallized by evaporation. The salts, which it forms with potash, soda, and ammonia, are very soluble; with other bases it gives compounds which are difficultly soluble. By a heat above that of boiling water, it is decomposed.*

SECTION III.

Of Milk.

The milk is a fluid, which is secreted, by 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 opaque liquid, of a white colour, with sometimes a slight tinge of blue or yellow. Its taste is sweetish and grateful; but va-

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* Ann. de Chim. et Phys. vi. 401.

ries occasionally, as does its colour also, with the food of the animal. Its specific gravity is variable; that of cows' 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; and the proportion may be ascertained by a very simple instrument, proposed by Mr. Johnson. It consists of a glass tube, 10 inches long, graduated into 100 equal parts, into which the recent milk is to be put, for spontaneous separation of the cream.* Cream 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. Cream, of the specific gravity 1,0244, is composed, according to Berzelius, of

Butter	4.5
Cheese	3.5
Whey	92.0
	100.

But as 92 parts of whey contain 4.4 of sugar of milk and salts, it follows that cream contains 12.5 per cent. of solid matter.

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 is 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, ether 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

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* Thomson's Annals, x. 304.

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 alkalies, and precipitable therefrom by acids, though in a state more like tallow than the original curd. During solution in alkalies, 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.

Berzelius found that the ashes, obtained by incinerating cheese, amount to 6.5 per cent. of its weight. The ash consists chiefly of earthy phosphates, with a little pure lime; but contains neither alkali nor oxide of iron. Cheese, digested with muriatic acid, loses its earthy phosphates, and afterwards burns without leaving any ash. The presence of so large a quantity of the earthy phosphates, in the most nutritious part of milk, may be regarded, Berzelius justly observes, as a wise provision of nature; and peculiarly adapts milk to the nutrition of young animals, in whose economy there exists the greatest demand for the earthy phosphates, for the purpose of ossification.

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* Essays, p. 267.

† Holland's Cheshire Report, p. 268.

Cheese is generally considered as insoluble in water; but if it be precipitated from milk by sulphuric acid, then well pressed, and digested with carbonate of barytes, cheese affords with water a yellowish solution resembling a solution of gum. The solution boiled in an open vessel becomes covered with a white pellicle, precisely as milk does, and acquires the smell of boiled milk.

Cheese produces, with the mineral acids, the same combinations as albumen and fibrin, though its neutral compounds are less soluble than those of fibrin. A great excess of acetic acid is required to dissolve cheese, and the neutral compound formed with this acid appears to be insoluble. When it has not been completely separated from butter, this floats upon the surface of its solution in acetic acid. Alcohol converts cheese into an adipocirous and fœtid substance.

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.* muriate of potash, 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 contains also a peculiar acid called *the lactic.*

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 its 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

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* Cheshire Report, page 262.

† 37 Phil. Mag. 6.

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 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 deposits, 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. Goat's 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.

The constituents of skimmed cows' milk are stated by Berzelius as follows:*

Water	928.75
Cheese, with a trace of butter . . .	28.00
Sugar of milk	35.00
Muriate of potash	1.70
Phosphate of potash	0.25
Lactic acid, lactate of potash, and a trace of lactate of iron	6.00
Earthy phosphates	0.30
	1000.

Of Chyle.

The chyle has been lately examined by Mr. Brande, who obtained it from the thoracic duct of an animal, about four hours after taking food. If taken at a longer interval, it is mixed with a greater or less proportion of lymph. When unmixed with blood, it has the following properties.

1. It is an opaque fluid of a perfectly white colour, without smell, and having a slightly salt taste, accompanied by some degree of sweetness.

2. It does not affect the colour of litmus or turmeric, but it slowly changes violet paper to green.

3. Its specific gravity somewhat exceeds that of water, but is less than that of blood.

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* Thomson's Annals, iii. 27.

4. In about ten minutes after being taken from the duct, it assumes the appearance of a stiff jelly, which in the course of 24 hours separates into two parts, producing a firm and contracted coagulum, surrounded by a transparent colourless fluid Its spontaneous changes, indeed, bear a striking resemblance to those which take place in blood.

The coagulated portion has a closer resemblance to the cheese of milk, than to fibrin. It is rapidly dissolved both by pure and subcarbonated alkalies, forming pale brown compounds. Its solution in liquid ammonia is of a reddish hue. The acids throw down a substance intermediate between fat and albumen, which an excess of nitric acid redissolves in the cold; and sulphuric, muriatic, and acetic acids, by boiling for a short time.

Sulphuric acid, diluted, dissolves the coagulum, unless the water be increased to six times the weigh of the acid. Alkalies do not precipitate the solution. It is transparent, of a pale brown colour, and, after the addition of alkali, is decomposed by infusions of tan.

When the coagulum is kept some weeks in one part of nitric acid, and 15 of water, it is converted into *adipocire*. Muriatic, acetic, and oxalic acids dissolve the coagulum; but neither citric nor tartaric have any action on it.

The serous part of the chyle, when heated, becomes slightly turbid, and deposits flakes of albumen. The clear liquid, by evaporation to half its bulk, deposits crystals, bearing a strong resemblance to sugar of milk. They are soluble in 20 parts of water at 60° Fahrenheit, or in four of boiling water, and the taste of the solution is extremely sweet. By nitric acid, they are converted into a white powder, having the properties of *saccholactic acid* as described by Scheele.

The destructive distillation of the serous part of chyle afforded a minute quantity of charcoal, with traces of phosphate of lime and of muriate and carbonate of soda.

From these experiments, it appears that chyle bears a striking analogy to milk, not only in its external appearance, but in chemical properties and composition. It must be acknowledged, however, that the results, which have been described, are not perfectly coincident with those obtained by Emmert and Vauquelin, each of whom submitted to analysis the chyle of the horse. Emmert was unable to discover the smallest trace of sugar of milk;* and Vauquelin found also, 1st, a large proportion of albumen; 2d, a smaller one of fibrin; 3d, a fatty substance, which gives to the chyle the appearance of milk; and 4thly, several salts, such as potash, muriate of potash, and pro-phosphate of iron.† Berzelius, also, appears to distrust the analogy between chyle and milk.‡

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* 80 Ann. de Chimie, 81.

† 81 Ann. de Chimie, 113.

‡ View of Animal Chemistry, p. 74.

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 solution 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 alkalies decompose it, and extricate ammonia. Oxy-muriatic acid renders it thick and dry; and reduces it to a state almost resembling parchment.

Berzelius found the mucus of the nose to consist of

Water	933.7
Mucus matter	53.3
Muriates of potash and soda	5.6
Impure lactate of soda	0.9
Albumen and animal matter, insoluble in water, but soluble in alcohol .	3.5
	1000.

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 alkalies. 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 resem-

bling 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.

A recent analysis of the humours of the eye by Berzelius, has determined their composition as follows:

	Aqueous Humour.	Vitreous Humour.
Water	98.10	98.40
Albumen	a trace	0.16
Muriates and lactates	1.15	1.42
Soda with animal matter soluble in water	0.75	0.02
	100.	100.

The lens of the eye was found to be composed of

Water	58
Peculiar matter	35.9
Muriates, lactates, and animal matter soluble in alcohol	2.4
Animal matter soluble only in water	1.3
Insoluble membrane	2.4
	100.

In the ashes of the crystalline lens, Berzelius found only minute traces of iron; but in those of the black matter which covers the choroid coat, he discovered a large proportion of the oxide of that metal.*

4. *Liquor of surfaces.* On the surface of every cavity throughout the body a fluid is constantly poured out, in sufficient quantity

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* Ann. de Chim. et Phys. v. 51.

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 opaque and gelatinous. By slow evaporation it left a residuum equal to one 13th of the whole. It was precipitated by oxymuriate 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 fœtus, is stated by Vauquelin and Buniva to be remarkable, in the cow, for affording a peculiar acid, already described under the name of the amniotic; but Dr. Prout, who has lately examined this liquor with much attention, was not able to detect any such principle.† The liquor, on which he made his experiments, had the sp. gr. 1.013. Its taste was bland and sweetish like fresh whey; and, when concentrated by evaporation, it yielded crystals of sugar of milk. It consisted of

Water	977
Albumen	2.6
Substance soluble in alcohol	16.6
Saline substances and sugar of milk	3.8
	1000.

In the human subject, the composition of the liquor of the amnios 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 muriate and carbonate of soda and some phosphate of lime. It is precipitated by heat, by acids, by alcohol, and by infusion of galls.

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[*] Nicholson's Journal, xiv. 147.

[†] Thomson's Ann. v. 417.

5. *Lymph.* The fluid found in the thoracic duct of animals that have been kept 24 hours without food, is perfectly transparent and colourless, and seems to differ, in no respect, from that which is contained in the lymphatic vessels. Its properties are described by Mr. Brande as follows:

1. It is miscible in every proportion with water.

2. It produces no change in vegetable colours.

3. It is neither coagulated by heat, by acids, nor by alcohol, but is rendered slightly turbid by the last mentioned agent.

4. It gives, on evaporation, a very sparing residuum, which turns the colour of violet paper green. By incineration, this matter gives a very little muriate of soda, but no iron.

5. When submitted to electrical action, there was an evolution of alkali, and a separation of albumen, at the negative pole. At the positive wire, muriatic acid only seemed to be evolved.*

6. *Synovia.* This 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 liquid, but soon becomes gelatinous; and, after remaining some time in this state, again assumes a fluid form and deposits a fibrous 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 diluted 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.

7. *The fluid of perspiration* has been examined by Berzelius. but under the disadvantage of operating on a very small quantity; A few drops, collected and evaporated on a watch glass, left a yellowish residue, having all the appearance, under the microscope, of the usual mixture of muriates of potash and soda with lactic acid, lactate of soda, and its accompanying animal matter. It reddened litmus, and dissolved in alcohol; and was, without doubt, of

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* Annales de Chim. xiv.

the same nature as the analogous matter found in other animal fluids. The acetic acid, which Thenard supposed he had discovered in the fluid of perspiration, was most probably a product of his mode of operating.

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.[*] The analysis of the urine has been prosecuted, also, with great success in this country by Cruickshank;[†] in Spain by Proust;[‡] and recently by that indefatigable philosopher, professor Berzelius of Stockholm.[§] And though some important facts have been contributed by other persons, yet it is chiefly to these 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 M. 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. Lactic acid.
9. Urea.
10. Gelatine.
11. Albumen.
12. Lactate of ammonia.
13. Sulphate of potash.
14. Sulphate of soda.
15. Fluate of lime.
16. Muriate of soda.
17. Phosphate of soda.
18. Phosphate of ammonia.
19. Sulphur.
20. Silex.

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[*] Annales de Chimie, xxxi. 48.

[†] Phil. Mag. ii. 240.

[‡] Annales de Chimie, xxxvi. 258.

[§] Thomson's Annals, ii. 416.

The presence of an uncombined acid in urine is shown by its invariably, when recently voided, reddening blue vegetable colours. This effect is owing partly to the phosphoric, and partly to the lactic and uric acids, which urine contains; and Vogel has lately endeavoured to show that carbonic acid is, also, one of its constituents.* The lactic and phosphoric acids form 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 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 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.‡

The existence of salts, containing sulphuric acid, in urine, is proved by adding muriate of barytes, to urine acidulated with muriatic acid. This excess of acid prevents the precipitation of the phosphates, which would otherwise be decomposed by the barytic salt. From the weight of the precipitate, Berzelius computes that the proportion of sulphuric acid in urine exceeds that of phosphoric acid.—If nitrate of barytes, with an excess of nitric acid, be employed, and if the urine, after depositing the sulphate of barytes, be evaporated, a further portion of sulphate of barytes is deposited in small hard crystals. Now the sulphuric acid, which

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* 93 Ann. de Chim. 71.

† Annales de Chimie, lxi. 256; and Thomson's Annals, ii. 416.

‡ Egan, Philosophical Magazine, xxiii. 298.

occasions this *second* production of the barytic sulphate, must have been *formed* during evaporation; and can only be accounted for by supposing, that a portion of sulphur, existing in the urine, has been acidified by the excess of nitric acid.

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 one 24th to one 36th 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 water, a number of shining white or yellowish scales are deposited, resembling the boracic acid, and in the proportion of five 8ths or seven 8ths 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 carbonate of ammonia, obtained from urine by distillation. (See the section on Urea.)

From the extract of urine, the peculiar substance, called the urea, may be separated by digesting the extract repeatedly with alcohol, and decanting the solutions, which are to be gently evaporated. Its proportion varies very considerably; but it has been stated, by Mr. Cruickshank, at about one 70th the weight of the urine, or one half the inspissated extract. The undissolved residue contains lactic acid and a number of neutral salts, consisting of muriate of potash, muriate of soda, phosphate of soda, and phosphate and lactate 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 muriates, at a certain degree of concentration, form a pellicle, which is to be removed while the liquor is hot. The solution, when cold, deposits 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, and Berzelius could not even discover a trace of it; 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 one 300th of the urine of this class of animals.*

If human urine be evaporated to the consistence of syrup only, and alcohol be added, the substance remaining undissolved is acid. This acid combines with ammonia, and the compound is soluble

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* Annales de Chimie, lxix. 311.

in alcohol. From this solution the ammonia is disengaged by lime; and from the new salt thus formed, the lime may be precipitated by oxalic acid, which leaves the *lactic acid* dissolved in water. By this process, a small part only of the lactic acid is obtained from urine; the greater portion of it being dissolved by the alcohol, together with the lactate of ammonia.

Albumen, gelatine, and mucus exist, also, in the urine, but in very variable 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 galls, by a precipitate which amounts, according to Mr. Cruickshank, to one 240th part the weight of the urine.

Mucus, also, is suspended in all newly evacuated urine, and affects its perfect transparency. If the urine be voided in different portions, the mucus, which naturally lines the urinary passages, is most abundant in the first, and less so in the subsequent portions. When recent urine is filtered, the mucus remains on the filter, in the form of transparent and colourless flocculi. The cloud, which appears in the urine during fever, is merely this mucus, which subsides more slowly than usual, in consequence of the increased specific gravity of the urine. From urine filtered when warm, a grayish white sediment falls in cooling, which gradually acquires a reddish hue and a crystalline form. The grayish powder is soluble in caustic potash, without any evolution of ammonia; but, as it becomes red and crystallized, potash disengages ammonia from it in abundance. Berzelius considers it, therefore, as urate of ammonia with excess of acid. The deposit is partly soluble, also, in acetic acid, which extracts a substance having the characters of mucus. There appears, indeed, to be an affinity between uric acid and mucus; for that acid separates most abundantly from urine, which has not been deprived of mucus by filtration. In some diseases of the bladder, its mucous secretion appears to undergo a considerable change, and to assume a purulent appearance.*

Sulphur was first 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. Sulphureted hydrogen gas, he finds also, is disengaged from urine which has been kept about fifteen days; a remark, which has since been made, also, by Vogel.

The same distinguished chemist supposed that he had discovered carbonic acid in urine, by examining the air bubbles which arise

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* Berzelius in Thomson's Annals, ii. 420.

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 refered 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 equivocal; and it is not improbable that this excellent chemist mistook the lactic for acetic acid. 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.

Berzelius discovered siliceous earth in urine by treating extract of urine, first with alcohol, then with water, and finally with muriatic acid. The silex remained in the form of a gray powder, which, by fusion with soda, became glass. Its source he apprehends to be in the water, which we drink, which almost universally contains silex.

With regard to the proportion of the different ingredients of urine, Berzelius finds that it differs essentially in the same individual, even from causes which have little influence on health. The following Table may be considered as showing its average composition.

Water	933.00
Urea	30.10
Sulphate of potash	3.71
——— soda	3.16
Phosphate of soda	2.94
——— ammonia	1.65
Muriate of soda	4.45
——— ammonia	1.50
Free Lactic acid	17.14
Lactate of ammonia	
Animal matter soluble in alcohol and accompanying the lactates	
Animal matter insoluble in alcohol	
Urea not separable from the above	

Earthy phosphates with a trace of Fluate of Lime	1.00
Uric acid	1.00
Mucus of the Bladder	0.32
Silex	0.03
	1000.

The 17.14 parts of lactic acid, &c. contain a quantity of water, which cannot be abstracted without decomposing those bodies. The uric acid is extremely variable; but in the particular instance, which furnished the above results, it was deposited on cooling. The earthy phosphates contain 11 per cent. more magnesia, than exists in the earth of bones, or in the ashes of blood. Much more potash is discoverable, also, in urine and in milk, than in blood.

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 consists 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 deposit a considerable portion of pink sediment (probably the *substance rosacée* 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 larger 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. And Dr. Wollaston has determined the proportion of uric acid to be greatest, in the urine of birds that feed on animal food. In the hawk, fed on flesh only, it was remarkably abundant; and the gannet, feeding solely on fish, discharged no solid matter except uric acid.* The uric acid has been found, also, by Dr. Prout† to constitute upwards of 90 per cent. of the excrement of an animal, belonging to a different class, the serpent called *boa constrictor*. Mr. Brande, some years ago, discovered it in the urine of the camel. But, on the other hand, Vauquelin has proved that it is entirely absent from the urine of the lion and tiger, though fed on flesh, and though their urine abounds in urea.‡

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* (or, as he termed it, *lithic*) 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 but 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 countryman. Several valuable additions have been since made to our knowledge of the subject by Dr. Pearson, Mr. Brande, and others; and an excellent history of all that was before known, combined with

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* Phil. Trans. 1810. † Thomson's Annals, v. 413.

‡ 82 Ann de Chim. 199. § See the Philosophical Transactions for that year.

much original matter, has been contributed by Dr. Marcet.* In the plates, which are annexed to this work, will be found the most exact representations of the several varieties of urinary concretions, that have yet been published.

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 or lithic 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. The ingredients of rarer occurrence are the *cystic oxide* of Dr. Wollaston, and the *xanthic oxide* of Dr. Marcet. 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 differances 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 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:

IV. Calculi which derive their characteristic property from oxalate of lime; and

V. Calculi composed of the substance discovered by Dr. Wollaston, and called by him *cystic oxide.*

I. The calculi composed entirely of uric acid are of very rare occurrence; but those, in which it prevails, and gives the character of the species, form a very considerable proportion, perhaps one half, of urinary concretions. 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

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* "An Essay on the Chemical History and Medical Treatment of Calculous Disorders." 8vo. London, 1817.

† Annales de Chimie, xxxvi.

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 one 5th 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 on a watch glass 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 or triple calculus is scarcely ever found without an admixture of some other substance, especially of phosphate of lime. Calculi of this sort are easily discriminated, from those of the first species, by their colour, which is white, 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 four 10ths of its weight, which is deposited on cooling, in the form of shining crystals. When exposed to heat it first becomes black, emits a smell of ammonia, and a white powder is left, which fuses imperfectly when the heat is more strongly urged. Most acids (even sulphuric acid of the specific gravity 1020) dissolve it rapidly, and deposit it again on the addition alkalies. Pure alkalies do not dissolve it, but disengage ammonia. To extract the phosphoric acid, Dr. Wollaston dissolved the calculus in acetic acid, and precipitated the phosphoric acid by an excess of acetate of lead To the clear liquor, sulphuric acid was added, which threw down the excess of lead, and, at the same time, formed sulphate of magnesia. Evaporation to dryness removed the acetic acid; and, by raising the heat, the sulphate of ammonia and excess of sulphuric acid were expelled; leaving the sulphate of magnesia pure, and capable of forming crystals by solution and evaporation.

III. The third species of calculus, composed chiefly of phosphate of lime, is usually, on its outer surface, of a pale brown colour, 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 considerably more harsh and rough.

The phosphate of lime calculus dissolves, though slowly, in diluted nitric, muriatic, and acetic acids (but not in the sulphuric acid of the specific gravity 1020), and is precipitated unchanged by alkalies. 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 makes angles of 60° and 120° with each other. This property Dr. Wollaston considers as a very delicate test of the phosphate of lime. When exposed to the blow-pipe, it first blackens, but soon becomes white, and, by intensely urging the flame, may at length be fused. When the phosphate of lime and ammoniaco-magnesian phosphate exist together, they compose a calculus, a fragment of which may be melted with great ease by the blow-pipe into a vitreous globule; and which has therefore been called by Dr. Wollaston, the *fusible calculus*. This calculus, when pulverized and acted upon by acetic acid, is only partially dissolved, the amoniaco-magnesian phosphate being taken up by the acid, and the phosphate of lime left. In this way, it is easy to ascertain the proportion of the two phosphates.

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 *mulberry calculi*. This epithet has been derived from their resemblance to the fruit of the mulberry. They are usually of a much darker colour than the other varieties, and are covered, generally, with a number of projecting tubercles; but the species comprehends, also, some perfectly smooth concretions of a pale colour. 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 when pulverized are soluble in muriatic and nitric acid; but not unless the acids are concentrated and heated. The solution by muriatic acid has a deep brown colour, but deposits white crystals on cooling. Pure alkalies 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, or by exposure to the blow-pipe. 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.

V. A new species of calculus from the human bladder was discovered, by Dr. Wollaston, about the year 1805. It appears to be extremely rare; for in 1810, when its properties were first described in the Philosophical Transactions, only two instances of it had occurred to its discoverer. With the assistance of Dr. Wollaston's clear and accurate description, and of the proper experiments, I have recognized two other examples, in a collection of calculi now in my possession; and Dr. Marcet has since detected it in no less than three instances.*

In external appearance, these calculi resemble more nearly the triple phosphate of magnesia than any other sort of calculus; but they are more compact, and do not consist of distinct laminæ, but appear as one mass, confusedly crystallized throughout its substance. They have a yellowish semitransparency, and a peculiar glistening lustre, like that of a body having a high refractive density.

Under the blow-pipe, the new calculus gives a peculiarly fœtid smell, quite distinct from that of uric acid. Distilled in close vessels, it yields fœtid carbonate of ammonia, partly solid and partly fluid, and a heavy fœtid oil; and there remains a black spongy coal, much smaller in proportion than from uric acid calculi.

It is so readily acted upon by chemical agents, that its characters are best taken from an enumeration of the few feeble powers, which it can resist. These are water, alcohol, acetic, tartaric, and citric acids, and saturated carbonate of ammonia; all which are incapable of dissolving it, except in very minute proportion.

Its solvents, on the other hand, are far more numerous. It is abundantly dissolved by muriatic, nitric, sulphuric, phosphoric, and oxalic acids; by potash, soda, ammonia, and lime water; and even by fully saturated carbonates of potash and soda. When, therefore, it is intended to separate it from acids, the carbonate of ammonia is best adapted to the purpose; and, for the same reason, the acetic and citric acids are best suited to precipitate it from alkalies.

Its combinations with acids crystallize in slender spiculæ, radiating from a centre, which readily dissolve again in water. Its compounds with alkalies form small granular crystals.

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* On Urinary Calculi, p. 82.

As this substance does not affect vegetable colours, and has all the chemical habitudes of an oxide, Dr. Wollaston distinguishes it by the name of *Cystic Oxide*. This name it is not worth while to alter, though Dr. Marcet has lately met with instances, in which its origin may be clearly traced to the kidneys and not to the bladder.

VI. Amongst the urinary calculi examined by Dr. Marcet, were two, the properties of which were found to differ from those of every known species. The first was of a reddish or cinnamon colour; was soluble in acids, though less readily than in alkalies, and gave with nitric acid a solution, which, when evaporated to dryness, had the remarkable property of assuming a bright lemon colour. It was distinguished from cystic oxide, by being much less soluble in acids; and, from uric acid, by considerably greater solubility in water. From the colour which it affords with nitric acid, Dr. Marcet has applied to it the term of *Xanthic Oxide* (from ξανθος, *yellow.*)

The other calculus exhibited a train of properties, corresponding exactly with those of fibrin; and should other examples of a similar kind occur, they may be distinguished, Dr. Marcet thinks, by the epithet *fibrinous calculi.*[*]

Such are the principal kinds of urinary concretions. If any addition were made to the five classes, under which they have been arranged, I would propose to add two others; the sixth 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 seventh those, in which the different substances are disposed in distinct 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.
2. ——— of uric acid and earthy phosphates intimately mixed.

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[*] On Urinary Calculi, chap. iv.

[†] 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, and Dr. Marcet's, on this point my own entirely agrees.

Species 3. Calculus 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 INGREDIENTS.

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, Horn, and Cartilage.

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 dissolve 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 remains 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.

Human bones were found by Fourcroy and Vauquelin (who have given a good general formula for the analysis of bones)[*] to contain some iron and manganese, and a larger proportion of magnesia than exists in the bones of herbivorous quadrupeds. This, indeed, might have been expected from the large quantity of magnesia, which is constantly passing off in human urine, but not in that of other animals. Alumine and silex were, also, found, by the same chemists, in human bones. Hildebrandt, however, has lately analyzed human bones, without being able to discover magnesia in them.[†]

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 Morroc-

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[*] 72 Ann. de Chim. 232.

[†] 88 Ann. de Chim. 199.

chini had previously found in enamel. Berzelius has given the following tabular view of the results of his analysis.*

	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 alkalies) 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

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* Annales de Chimie, lxi. 257.

classes. The first, from their resemblance to porcelain, he has termed porcellaneous shells. To this class belong the several species of *voluta*, *cypræa*, &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 arranged 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. The shells of eggs, Mr. Hatchett found, are composed of barbonate of lime, with a small proportion of phosphate of lime, cemented by animal matter. Vauquelin has lately added, to these ingredients of egg-shells, carbonate of magnesia, iron, and sulphur.*

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 one 300th part. It appears to consist principally of gelatine and coagulated albumen.

Of Cartilage.

Chevreul has analyzed the cartilage of the *squalus peregrinus*. He found it to be sparingly soluble in water; the solution was viscid; foamed on agitation; restored the colour of reddened litmus; and was precipitated by sulphuric, nitric, or muriatic acid, an excess of which re-dissolved the precipitate. Oxymuriatic acid occasioned a deposit, as did also the pro-nitrate of mercury and the sub-acetate of lead. Infusion of galls produced only a slight cloud.

When boiled with alcohol, the cartilage shrunk in bulk, and became opaque by losing water. The first washings had the colour of ammoniuret of copper, and deposited an animal matter. From the residue of the evaporation of these washings, hydrate of lime disengaged a large quantity of ammonia.

Cartilage dissolved in muriatic acid, and the solution was precipitated by infusion of galls. Nitric acid dissolved it, and when evaporated, gave oxalic acid, nitrate of soda, a yellow matter, different from that of Welther, and an odorous oil.

By destructive distillation, it gave the ordinary products of animal substances.

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* 81 Ann. de Chim. 304.

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 reddish 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, soluble in water and in alcohol, and first described by Thouvenal. The entire muscle, when calcined, leaves about 5 *per cent.* of its weight of saline matter, composed chiefly of phosphates of soda, ammonia and lime, and carbonate of lime.

Lean flesh, Berzelius finds, is composed of nearly three-fourths its weight of fluid. This fluid contains a free acid; and the extract, which Thouvenel described, is the same acid syrupy mass, which is met with in milk and urine, and which consists of lactic acid, an alkaline lactate, and the animal matter, that always accompanies the lactates. The fluids of muscle abound much more in this syrupy extract, and contain more phosphate of soda, than the blood. The solid fibre is interwoven with the cellular texture, and is furnished with minute veins and nerves. It agrees, in chemical properties, with the fibrin of the blood; and it is soluble, except the cellular texture of veins and nerves, in acetic acid. By boiling it becomes, like the fibrin of blood, insoluble in acetic acid, and imparts to the water, with which it has been boiled, a constituent part, which has a strong and pleasant taste of flesh, and cannot be gelatinized. When this is dissolved, and mixed with the uncoagulated part of the humours of the flesh, it forms what is called *broth*, the strength and taste of which depend, not only on the dissolved gelatine of the cellular texture, but also on the fibrin, the taste of which it retains. The taste does not depend on the extractive matter of Thouvenel; for flesh, from which this extract has been separated, still gives a palatable though colourless soup.

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, beside 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. There is an essential difference, however, between cellular or serous membranes, and mucous membranes. The latter furnish no gelatine by boiling; and are sooner destroyed than any animal substance, the brain excepted, by maceration in water, or by the action of acids.

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 membranes 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. Alkalies however dissolve it; and, in this respect, it agrees with coagulated 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 gelatinates on cooling, or, by farther evaporation, may be wholly converted into glue.

The true skin is composed, therefore, almost entirely of gelatine; 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 reception 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 oxymuriatic 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 Vauquelin. He effected a complete solution of it in water by using a Papin's digester. The application of the proper temperature required, however, some caution; for if raised too high, the hair was decomposed and gave carbonate of ammonia, empyreumatic oil, and sulphureted 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 oxymuriatic 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 alkalies, 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 alkalies 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; and Vauquelin has published an elaborate set of experiments on the same subject.*

The medullary substance of the brain is of a soft censistence, 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 six 10ths of its weight; but one third of the portion, which has been dissolved, is again deposited on cooling in the form of shining 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. It stains paper like a fixed oil, is soluble in 20 times its weight of boiling alcohol; and is miscible with water into a sort of emulsion, from which it does not separate on standing, and which is not acid. From the results of its combustion, both alone and with nitre, Vauquelin infers that it contains uncombined phosphorus.

Alcohol, by digesting with brain, acquires a greenish colour, which it retains even after filtration. By evaporation to one eighth its bulk it deposits a yellowish oily fluid, and the liquor itself is yellowish. When repeated quantities of alcohol are digested on the same portion of brain, the alcohol is tinged a sapphire blue colour. These colours remain, till the whole alcohol is expelled by heat, when the residuary matter acquires a yellow tinge, of

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* Thomson's Annals, i. 332.

greater or less intensity. The latter portions of alcohol, do not, like the first, deposit oil on standing.

The liquid oil, after being washed with water, and evaporated to dryness at a gentle heat, has a reddish brown colour, and a smell resembling that of the brain itself, but stronger. Its taste is like that of rancid fat. It forms, with water, an emulsion which is coagulated by the addition of acids, and by infusion of tan. It is soluble in hot alcohol; and the greater part separates on cooling. Though freed from all acid by washing, yet it furnishes phosphoric acid by being burnt either alone or with nitre; and hence we must admit the presence of phosphorus in this fatty matter, as well as in the crystalline substance. From the latter, indeed, it appears to differ only in containing a quantity of animal matter, which is separable by cold alcohol.

The acohol, from which the fatty matter has separated, has a yellow colour, a taste of the juice of meat, and gives marks of acidity. It contains super-phosphate of potash, and a peculiar animal matter, which by its solubility in cold alcohol and water; by its property of being precipitated by infusion of galls; by its reddish brown colour, its deliquescence, its taste and smell of the juice of meat, may be regarded as identical with the substance, which Rouelle formerly called saponaceous extract of meat, and to which Thenard has given the name of *Osmazome*. It is this substance which tinges the fatty matter, extracted from brain by alcohol.

The portion of brain which remains after the full action of alcohol, is a greyish white matter in the form of flocks, which resembles cheese externally. In drying, it assumes a gray colour, a semi-transparency, and a fracture similar to that of gum arabic. It appears, as Fourcroy supposed, to be perfectly identical with albumen; and it is this ingredient, which occasions the coagulation of brain, when mixed with water, by heat, acids, metallic salts, &c. The alkaline solution of this part of brain precipitates acetate of lead of a dark brown colour, showing obviously the presence of sulphur.

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 distilled in close vessels, 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 sulphureted and carbureted hydrogen gases are formed. In the retort a coal remains which affords traces of phosphates of lime and soda.

The mass of brain, as appears from the experiments of Vauquelin, is composed, therefore, of 1st, two fatty matters, which are probably identical; 2dly, albumen; 3dly, osmazome; 4thly, different salts; and, among others, phosphates of potash, lime, and magnesia, and a little common salt; 5thly, phosphorus; 6thly, sulphur. The following is to be considered merely as an approximation to their proportions.

1. Water	80.00
2. White fatty matter.	4.53
3. Red fatty matter	0.70
4 Albumen	7.00
5. Osmazome	1.12
6. Phosphorus	1.50
7. Acids, salts, and sulphur . . .	5.15
	100.

ELEMENTS

OF

EXPERIMENTAL CHEMISTRY.

PART II.

DIRECTIONS FOR EXAMINING MINERAL WATERS, AND MINERAL BODIES IN GENERAL.

CHAPTER I.

ANALYSIS OF MINERAL WATERS.

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 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 deposit 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 deposit. 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 carbonate of lime or magnesia. A mineral water, containing iron, deposits 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. Sulphureted hydrogenous waters deposit 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 returned 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 in some cases considerably 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 crytallized 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, 41½ 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.

For the analysis of mineral waters, and of mineral bodies in general, tests of the utmost purity are required. It will be found extremely useful to keep the three mineral acids, the alkalies, and the alkaline carbonates, in a liquid form, and of such strength, that one measure of the one will neutralize either one measure, or some simple multiple of one, of the other. The advantage, thus obtained, is, that when it is necessary to precipitate a substance, held in solution by an acid, we can take just the quantity of alkali required for the purpose; a precaution of great use in all cases, where the substance to be precipitated is re-dissolved by adding an excess of the precipitant; as happens, for instance, with respect to alumine. It is of no consequence of what precise strength these solutions are; but the following will be found of convenient density; and, though perhaps the numbers may require a little correction in some instances, yet they are sufficiently accurate for the purpose they are intended to serve.

Liquids.	Sp. gravity.	Measures for saturation.	100 Water gr. measures contain
Sulphuric acid	1.135	1	15.7 gr. real
Nitric acid	1.143	1	23.27 gr. do.
Muriatic acid	1.074	1	11.89 gr. do.
Potash	1.100	2	9.3 gr. do.
Soda	1.070	2	6.1 gr. do.
Ammonia	0.970	1	
Subcarb. potash	1.248	1	31. gr. dry
——— soda	1.110	2	11.5 gr. dry
——— ammonia	1.046	2	

The first column of the foregoing Table expresses the specific gravity of the liquid test; the second, the number of measures of each required for saturating any of the others; and the third, the number of grains of real acid, real alkali, or solid carbonate, in 100 measures of solution, each measure being equal to a grain of water. From the last column, and with the aid of the *Scale of equivalents*, it is easy to calculate how much any other test, of known composition, is required for decomposing 100 water grain measures of any of the solutions in the Table. Thus 15.7 grains of real sulphuric acid will be found, by Dr. Wollaston's scale, to be capable of decomposing 41.2 grains of dry muriate of barytes (equal to 48 of the crystallized muriate.) It may be adviseable, therefore; to keep a solution of muriate of barytes, of such strength, that 400 water grain measures may contain 48 grains of the crystals; in which state the solution will be more convenient for use, than if it were stronger. The same plan may be extended to other tests, the quantities of which may thus be accurately adjusted to the purpose intended to be answered. Indeed, it would contribute very much to accuracy, as well as to economy, if all the chemical solutions, kept for purposes of research, had their specific gravity, and the proportion of their ingredient in a real or solid state, marked on the labels of the bottles containing them,—a practice of which I have long experienced the advantages.

When filters of paper are used for collecting precipitates, great caution is necessary that their weight should be the same, before and after the experiment. Even during the time of weighing, they acquire moisture from the atmosphere; and it is therefore necessary, before taking their weight correctly, to obtain an approximation to it; after which, the paper being again dried, less time is occupied in determining it within the fraction of a grain. The unsized paper, which accompanies Mr. Watt's copying machines, answers the purpose extremely well. It is this which was always employed by Berzelius, whenever he used filters at all; but their use, when the nature of the precipitate admits, he thinks should be avoided.* I am not inclined, however, to coincide in his rejection of filters, and am of opinion that, when they are carefully and skilfully used, there is no better way of collecting and drying precipitates. In order to wash away, completely, all soluble matter, a stream of distilled water should be directed upon the edge of the paper, when laid in the funnel, either from a dropping tube or from the bottle, fig. 25, *a*.

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.

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* 78 Annales de Chimie, 31.

If the colour of the infusion tend 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. It indicates, also, the presence of alkalies, which turn it green.

Paper stained with the juice of the March violet, or with that of the scrapings of radishes, answers a similar purpose; being turned red by acids, and green by alkalies. In staining paper for the purpose 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 Philosophical 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.

I. If the infusion redden the unboiled, but not the boiled water, under examination; or, if the red colour, occasioned 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. Sulphureted hydrogen gas, dissolved in water, also reddens litmus, but not after boiling; and its presence is easily discovered by its offensive smell.

To ascertain whether the change be produced by carbonic acid or by sulphureted 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. Sulphureted hydrogen may also be contained, along with carbonic acid, in the same water; which will be determined by the tests hereafter to be described.

In some cases, when the change of colour is so slight as to be scarcely perceptible, it may be proper to use half a pint or more of the water which we are examining, and to mix it with the infusion of litmus in a broad shallow glass vessel, set on a sheet of white paper; using for the sake of comparison a similar vessel of distilled water, coloured by an equal quantity of the litmus infusion.

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.* The dark blue paper, which is

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* See Kirwan on Mineral Waters, page 40.

generally wrapped round loaves of refined sugar, is not discoloured by carbonic acid or sulphureted 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,—Acid Tincture of Cabbage,—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 alkalies and pure earths, and by carbonated alkalies and earths.

2. Turmeric paper and tincture are changed to a reddish brown by alkalies, whether pure or carbonated, and by pure earths, but not by carbonated earths. Dr. Bostock finds that it is obviously affected by a solution, containing only one 2000th of its weight of potash.

3. The red infusion of Brazil-wood and paper stained with it, become blue by alkalies 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. Infusion of the leaves of red cabbage in very dilute sulphuric acid has a red colour, which is rendered blue by alkalies, when added in quantity just sufficient to neutralize the acid. Hence, if the infusion be made with a known quantity of acid, it becomes a test of the quantity of alkali in any solution. As it is apt to spoil by keeping, it should be prepared fresh when wanted, from the leaves dried carefully and preserved in corked vials.

5. Syrup of violets, when pure, is, by the same agents, 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

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* 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 recommends 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.

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 discovered in water fresh from the spring, by a slowly-formed and dark cloud, surrounding the re-agent.*

It has been remarked by Mr. R. Phillips, that the presence of carbonate of lime rather heightens the colour produced by this test, when the iron is at the minimum of oxidation; but that when the metal is in the state of per-oxide, it diminishes the effect so much, that a very minute quantity of iron may elude entirely the action of the test.

IV.—*Sulphuric Acid.*

1. Sulphuric acid discovers, by a slight effervescence, the presence of carbonic acid, whether uncombined or united with alkalies 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 sulphureted hydrogen gas, Mr. Westrumb infers the presence of hydro-sulphuret of lime. In this case, sulphate of lime is precipitated.†

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

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* Klaproth, vol. i. page 279.

† Nicholon's Journal, xviii. 40.

sulphureted 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 water) 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. In this case, carbonate of lime is separated, by heating the water, in the form of a white sediment, or of a sediment tinged yellow by oxide of iron, when that metal is also present.

3. If oxalic acid occasion a precipitate even after boiling, the solvent of the lime is a fixed acid. A considerable excess of any of the mineral acids, however, prevents the oxalic acid from throwing down a precipitate, even though lime be present; because some acids decompose the oxalic, and others, dissolving the oxalate of lime, prevent it from appearing.*

The oxalate of ammonia, or of potash (which may easily be formed by saturating the respective carbonates of these alkalies 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 greatly supersaturated with muriatic or nitric acids; and, if such an excess be present, it must be neutralized, before adding the test, with pure ammonia. A precipitation will then be produced. The presence of other earths in solution, along with lime, also impedes decomposition by oxalic acid and the oxalates. Thus a watery solution of sulphate of magnesia and sulphate of lime is not precipitated by these tests.

The quantity of lime contained in the precipitate may be known, by first calcining it with excess 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 use of oxalate of ammonia, that excellent analyst finds, is in some degree limited by its property of precipitating the salts of iron.

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* See Kirwan on Waters, page 88.

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 Alkalies and Carbonated Alkalies.*

1. The pure fixed alkalies precipitate most of the earths and all the 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 alkalies; and if too much of the alkali be added to a more concentrated solution, the alumine is re-dissolved. If the alkali be perfectly free from carbonic acid, it does not precipitate lime, strontites, or barytes, except when those earths are held in solution by carbonic acid in excess, and then in the state of carbonates.

As the alkalies 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, at 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 alkalies 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 most of the earthy and all the metallic salts; but if quite pure, it does not precipitate lime, barytes, or strontites, when held in solution by any acid, except the carbonic. It has this advantage as a precipitant of alumine, that it does not re-dissolve that earth when added in excess. To any liquid that contains copper or nickel in a state of solution, it imparts a deep blue colour; 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 solutions at common temperatures. 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 arsenious 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 sulphureted 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 bluish, 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 425½ 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, 454¾ 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 alkalies and earths. The agency of the alkalies 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 inferred. To remove uncertainty, whether a precipitation be owing to sulphuric or muriatic acid, a solution of sulphate of silver may be employed in the first instance, which, when no uncombined alkali or earth is present, denotes with certainty the presence of the muriatic 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.* Mr. Meyer of Stettin as-

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* Nicholson's Journal, xvii. 361.

signs, however, a much more extensive power to nitrate of silver, as a test of muriatic acid.*

4. The solutions of silver are also precipitated by sulphureted 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 sulphureted hydrogen and of hydro-sulphurets of alkalies, 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 sulphureted 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 alkalies 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 one 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.

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* Thomson's Annals, v. 23.

† See chap. xix. sect. 4, vi.

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 alkaline carbonates; but the precipitate thus occasioned 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. p. 168) about 45⅓ of sulphuric acid of the specific gravity 1850; according to Claryfield (Nicholson's Journal, 4to. iii. 38), 33 of acid, of the specific gravity 2240; according to Thenard, after colcination, 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 indicate 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 precipitation of 71 grains of sulphate of lime, of ordinary dryness. The results of my own experiments are stated in vol. i. page 350. From these it follows, that 100 grains of ignited sulphate of barytes denote 57 of calcined sulphate of lime; or 73 of the same sulphate, dried by a temperature of only 160° Fahrenheit. Desiccated sulphate of magnesia, when decomposed by muriate of barytes, affords twice its weight of the barytic sulphate.

2. Phosphoric salts occasion a precipitate also, which is soluble in muriatic acid without effervescence.

XVI.—*Triple or Ferro-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 addition of an acid, nor does it *immediately* precipitate muriate of barytes.

Prussiate of potash is a very sensible test of iron; with the solu-

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[*] Saussure, Thomson's Annals, vi. 430.

tions 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 alkalies or earths, which, if present, 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 solvent is a fixed acid, the nature of which must be ascertained by other tests.

Doubts had been thrown, by several chemical writers, on the fitness of the ferro-prussiate of potash for determining the *quantity* of iron in solutions of that metal. But Mr. Porrett, in his able inquiry into the nature of the triple prussiates, has shown that, with certain precautions, the ferro-prussiate of potash is fully adequate to this purpose.* It is necessary to observe,

1st. That if the ferro-prussiate, after being dissolved in water, gives, immediately, a blue precipitate by the addition of muriatic acid, it is not pure, and will afford a fallacious result.

2dly. That if the salt, however pure, be added, *in excess*, to a solution of iron *containing an excess of acid*, and then heated, the prussian blue thrown down will weigh more than it ought; because some is furnished by the decomposition of the ferro-prussic acid, contained in that part of the salt, which has been added in excess.

3dly. That prussian blue, even after it has been formed, is materially acted upon by a mixture of nitric and muriatic acids, and in some degree, by the muriatic acid alone at a boiling heat.

4thly. That prussian blue, when precipitated, often carries with it sulphate of potash, derived from the liquid from which it is thrown down; and that this sulphate adheres to it so obstinately, that several washings with water, acidulated with sulphuric acid, are necessary to detach it.

5thly. That if the solution, to which the test is applied, contain not only iron, but alumine, oxide of copper, or any other substance, which the test is known to precipitate, *that* substance should be removed, by the usual means, previously to the application of the test.

Suppose then, for example, that we have barytes, alumine, magnesia, and oxides of iron and copper, in a state of solution by nitro-muriatic acid. The solution, if not already neutral, may first be rendered so by the cautious addition of ammonia. The barytic salt may next be decomposed by a solution of sulphate of soda, added till it ceases to occasion a precipitate. Ammonia, added to the residuary liquor, throws down the other earths and oxides, and

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* Phil. Trans. 1814, p. 538.

an excess of it will re-dissolve the oxide of copper. From the insoluble part, consisting of alumine, magnesia, and oxide of iron, solution of pure potash will remove the alumine. The oxide of iron and magnesia may then be re-dissolved in any suitable acid; and, to the solution, neutralized, or nearly so, by ammonia, if necessary, the ferro-prussiate may be poured, till it ceases to produce any effect, taking care to add as little excess as possible. The precipitate washed, dried at a steam heat, and weighed, will indicate in every 100 grains, 34.235 grains of peroxide of iron.

Besides iron, the prussiated alkalies 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, therefore, be proper, if a salt of alumine be indicated by other tests, to examine the precipitate affected by prussiate of potash. This may be 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.

According to Klaproth (ii. 55), solutions of yttra (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 consist of prussiate of yttria. This precipitate disappears on adding an acid, and hence may be separated from prussiated iron. The same accurate chemist states, that the prussian test has no action on salts with base of glucine (ii. 55); but that it precipitates zircon from its solutions (ii. 214.)

The prussiated alkalies decompose, also, all metallic solutions excepting those of gold, platinum, 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 ammonia 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. Saunder's Treatise on Mineral Waters.

The succinic test is prepared by slightly super-saturating carbonate of soda or ammonia with succinic acid. In applying the test, it is necessary not to use more than is sufficient 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, until it ceases to produce any tubidness. A brownish precipitate is obtained, 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 67½ 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 action, 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,* precipitates glucine; and the same test, according to Klaproth (ii. 214,) throws down zircon from its solutions.

To separate all the iron and alumine from any water, long boiling is necessary with free access of air, in order that the iron may be completely oxidized; for the succinates have no action on salts containing the protoxide of iron.

XVIII.—*Benzoic Acid, and Benzoate of Ammonia.*

Benzoic acid, or, still better, benzoate of ammonia, precipitates iron readily and entirely; and being much cheaper, and more readily obtained, than succinate of ammonia, may be substituted for the latter salt. It has, also, one advantage, that it does not decompose the salts of manganese.†

XIX.—*Phosphate of Soda.*

A method of completely precipitating magnesia from its solutions has been suggested by Dr. Wollaston. It is founded on the property which fully neutralized carbonate of ammonia possesses; first to cause the solution of the carbonate of magnesia, formed when it is added to the solution of a magnesian salt, and afterwards to yield that 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 paper, 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 evaporation. 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; 44 carbonate; about 66 of muriate of magnesia;

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* Journ. des Mines, No. lxx.

† Thomson's Annals, ix. 163; Phil. Mag. xl. 258.

and 62 of desiccated, or double that quantity of crystallized, sulphate of magnesia. If, instead of drying the precipitate at a gentle heat, we calcine it, we may then reckon the calcined phosphate of magnesia to indicate, in every hundred grains, 38.5 of magnesia, or to be equivalent to 226 grains of the crystallized sulphate of that earth.

XX.—*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 alkalies, potash may be detected by the nitro-muriate of platinum, which distinctly and immediately precipitates 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.

XXI.—*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 salts with earthy and metallic bases, decompose soap, and occasion that property in waters which is termed hardness.

XXII.—*Alcohol.*

Alcohol, when mixed with any water, in the proportion of about an equal bulk, precipitates all the salts which it is incapable of dissolving. (See Kirwan on Waters, page 263.)

XXIII.—*Hydro-Sulphuret of Ammonia.*

This and other sulphurets, as well as water saturated with sulphureted hydrogen, may be employed in detecting lead and arsenic; with the former of which they give a black, and with the latter a yellowish precipitate. As lead and arsenic, however, are never found in natural waters, I shall reserve, for another occasion, 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 mercury, 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 manganese.

Acid, sulphuric. Solution of pure barytes, IX. Barytic salts, XV. Acetate of lead, XII.

Alkalies in general. Vegetable colours, II. Muriate of lime, XX.

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 boiling;—by pure alkalies, VII. Solution of soap, XXI.

Hydro-sulphuret of lime. Sulphuric acid, IV. Nitrous acid, V.

Iron dissolved by carbonic acid Tincture of galls, III. 1. Prussiate of potash, XVI. 1. Succinate of ammonia, XVII. Benzoate of ammonia, XVIII.

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 alkalies, 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, XIX.

Muriates of alkalies. 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 alkalies by boiling. Succinates, XVII. 2.

Sulphate of lime. Barytic solutions, IX. and XV. Oxalic acid, and oxalates, VI. A precipitate by alkalies not soluble in dilute sulphuric acid.

Sulphurets of alkalies. Polished metals X. Smell on adding sulphuric or muriatic acid. Nitrous acid, V.

Sulphureted 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 globe or 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 is lost by evaporation. The disengaged gas is to be 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 itself be expanded, and portions will continue to escape into the graduated jar, till the water has attained its maximum of temperature. This portion must be measured, 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 127. 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

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* The vapour of putrefying animal or vegetable matter dissolved in water, according to Klaproth, vol. i. p. 590, often gives a deceptive indication of sulphureted hydrogen.

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; sulphureted hydrogen; nitrogen gas; oxygen gas;* and, in the neighbourhood of volcanoes only, *sulphurous acid gas.*

To determine the proportion of the gases, constituting a mixture obtained from any mineral water in the foregoing manner, the following experiments may be made. If the use of re-agents has not detected the presence of sulphureted 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 152.)

If sulphureted 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 sulphureted hydrogen, but not the carbonic acid gas. I apprehend, however, that a more eligible mode will be found to be, the condensation of the sulphureted hydrogen by oxymuriatic acid gas (obtained from muriatic acid and hyper-oxymuriate of potash;) adding the latter gas very cautiously, as long as it produces any condensation. Or, perhaps a better plan of effecting the separation will be the following: Half fill a graduated phial with the mixed carbonic acid and sulphureted hydrogen gases, and expel the rest of the water by oxymuriatic 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 oxymuriatic acid gas will thus be absorbed; and very little of the carbonic acid will disappear. Supposing that, to ten cubic inches of the mixed gases, ten inches of oxymuriatic gas have been added, and that, after absorption by standing over water, five inches remain: the result of this experiment shows, that the mixture consisted of equal parts of sulphureted hydrogen and carbonic acid gases.

Mr. Westrumb ascertains the proportion of sulphureted hydrogen and carbonic acid gases, by the following method. He introduces 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 sulphureted 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 proposed.

Whenever this complicated admixture of gases occurs, as in the case of the Harrowgate-water, it is advisable to operate separately on two portions of gas, with the view to determine, by the one, the quantity of carbonic acid and sulphureted hydrogen; and that of nitrogen and oxygen by the other. In the latter instance, remove both the absorbable gases by caustic potash; and examine 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. p. 144. Sulphurous acid gas may be detected by its peculiar smell of burning brimstone, and by its discharging the colour of an infusion 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. Wedgewood; 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 deposit 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 reddish brown colour.

1. In order to discover the quality and quantity of the ingredients, evaporate to dryness; weigh the residuum; add above 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 carbonates 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. XIX.

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.

Some of the salts obtained by the action of alcohol, it is supposed by Grotthuss, are actually formed by its operation. Sulphate of soda and muriate of magnesia, for example, when found in an alcoholic solution, result, he imagines, from the mutual decomposition of sulphate of magnesia and muriate of soda.*

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 (p. 417, 418,) and of acids by the tests (p. 416, 417.) The vegetable alkali, or potash, may be distinguished from the mineral, or soda, by saturation with sulphuric acid, and evapora-

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* Ann. de Chim. et Phys. iv. 366.

tion to dryness; the sulphate of soda being much more soluble than that of potash; or, by super-saturation, with the tartarous acid, which gives a soluble salt with soda, but not with potash. Muriate of platinum, 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 beside 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.

Dr. Murray's Formula for the Analysis of Mineral Waters.

Some ingenious views respecting the analysis of mineral waters have lately been taken by Dr. Murray, of Edinburgh.* In proceeding by the method of evaporation, the salts obtained are frequently, he conceives, the products of the operation, and not the original ingredients of the water For example, though we may obtain from a mineral water, sulphate of lime and muriate of soda, yet it is probable, he thinks, that the water, in its natural state, held in solution both sulphate of soda and muriate of lime, which, though incompatible salts, if presented to each other in dense solutions, may yet exist, without mutual decomposition, when diffused through a large quantity of fluid He argues, therefore, that we attain a much nearer approximation to the true composition of a mineral water, by disregarding the salts resulting from its evaporation; and, instead of this, determining with extreme precision the elements, or acids and bases, of which those salts are composed. The peculiar mode of combination, in which they exist in the water submitted to ananysis, can only, he thinks, be inferred by considering the most probable views of their binary composition.

Having gained a general idea of the nature of any mineral wa-

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* Edinb. Transact. viii. 250, or Thomson's Annals.

ter, by the agency of the tests already described, Dr. Murray recommends that we proceed to its minute analysis in the following manner.

1. Reduce the water, by evaporation, as far as can be done without occasioning any sensible precipitation or crystallization.

2. Add a solution of muriate of barytes, as long as it occasions a precipitate, and no longer. By an experiment on a separate quantity, examine whether the precipitate effervesces with dilute muriatic acid, and whether it is entirely dissolved by that acid. If entirely soluble, dry and weigh it, and allow 22 grains of carbonic acid for every 100 grains. If it do not effervesce, or dissolve, we may consider it as sulphate of barytes, and reckon that it contains, in a dry state, 34 grains of sulphuric acid in every 100. If it be partly soluble with effervescence, and partly insoluble, it consists both of carbonate and sulphate, the former of which may readily be separated from the latter by dilute muriatic acid; and the precipitate being weighed in a dry state, both before and after the action of the acid, we learn the quantity of each; what remains being the sulphate only.

By the evaporation, the *carbonic acid* is removed, and the *sulphuric acid* is separated by the barytic salt. The next object is to discover the kind and quantity of the bases present; and then to find the quantity of muriatic acid, originally contained, in the water.

3. To the clear liquor add a saturated solution of oxalate of ammonia, as long as any turbid appearance is produced. Collect the precipitate, which consists of oxalate of lime; dry it; and, by calcining it at a low red heat, convert it into a carbonate, which may be changed into sulphate by a slight excess of sulphuric acid. The sulphate of lime, after ignition, contains 41.5 of lime in 100.

4. The next step is to separate the *magnesia*, which may be done as follows: let the clear liquid, remaining after the precipitation of the oxalate of lime, be heated to 100° Fahrenheit, and, if necessary, reduce a little by evaporation; and then, add to it, first a solution of carbonate of ammonia, and afterwards of phosphate of ammonia, at long as any precipitation ensues. Wash the precipitate, dry and calcine it at a red heat for an hour, after which 100 grains may be estimated to contain 40 of magnesia.

5. To estimate the *soda*, evaporate the liquor, remaining after the preceding operations, to dryness, and expose the dry mass to heat as long as any vapours exhale, raising it, in the end, to redness. The residual matter is muriate of soda, 100 grains of which are equivalent to 53.3 soda, and 46.7 of ammoniatic acid.

6. It is possible that the muriatic acid, deduced from the residuary common salt, may exceed the true quantity, and that a part may have been introduced by the muriate of barytes. Or, on the other hand, if muriate of lime or magnesia were present in the water, the ammonia, by which those earths were separated, would form, with the muriatic acid quitted by them, a salt, which will

have been dissipated by heat; and consequently the muriatic acid will have been stated too low. To decide this, the simple rule is, to suppose the elements, obtained by the analysis, combined in binary compounds, according to the known proportions in which they unite. The excess or deficiency of muriatic acid will then appear; and the amount of the excess, being subtracted from the quantity of muriatic acid existing in the muriate of soda obtained; or the amount of the deficit, being added to that quantity, the real quantity of muriatic acid will be apparent.—As a check on this operation, it may be proper to estimate directly the quantity of muriatic acid in a given portion of the water, by first abstracting any sulphuric or carbonic acid by nitrate of barytes, and then precipitating the muriatic acid by nitrate of silver. The real quantity of muriatic acid will thus be found; and the result will form a check on the other steps of the analysis; for the other ingredients must bear that proportion to the muriatic acid which will correspond with the state of neutralization.

Having thus discovered the different acids and bases, and determined their quantities, it remains to determine the state of combination in which they exist. They may either be considered as forming simultaneous combinations, or as existing in the state of binary compounds. In the latter case, it is probable that the acids and bases are so united as to form the most soluble compounds, and in this way we may state them. It may also be proper to give the quantity of binary compounds obtained by evaporation, or by any other direct analytic process. For example, the elements of the salts in a pint of sea-water, as determined by Dr. Murray's analysis,* are,

Lime	2.9 grains
Magnesia	14.8
Soda	96.3
Sulphuric acid	14.4
Muriatic acid	97.7
	226.1

The compound salts, as obtained by evaporation, are,

Muriate of soda . . .	180.5 grains
———— magnesia .	23.
Sulphate of magnesia .	15.5
———— lime . . .	7.1
	226.1

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*Edinb. Phil. Trans.

But the salts existing in a pint of sea-water, in its natural state, before subjecting it to evaporation, may be calculated to be

Muriate of soda . . .	180.5 grains
——— magnesia .	18.3
——— lime . . .	5.7
Sulphate of magnesia .	21.6
	226.1

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, 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 attended 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 can only be resolved into oxygen and a metallic basis. Such are lime, magnesia, alumine, silex, &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 substance that requires 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 allowed 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 metallic 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 oxygen 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 is 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° Fahrenheit. 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 the 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 ÷ 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 distinguished 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 445,) 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, p. 433.

(*b*) *Alkalies.* These are characterized by their effect on vegetable colours, and by the other properties enumerated, vol. 1. p. 212.

(*c*) *Salts with metallic bases.* Metallic salts afford a very copious precipitate when mixed 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 ferro-prussiate of potash occasions no precipitation, afford a precipitate, 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 ferro-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, ferro-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 washing to what has been poured off. The decanted solution must next be mixed with the alkaline one, and the precipitated 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 alkalies may be distinguished by adding to the solution a little tartarous acid, which precipitates the former but not the latter; or by muriate of platinum, which acts only on the vegetable alkali.

Having ascertained the basis of the salt, the acid will easily be

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* 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.

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 inquiry 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 general, however, it is not usual to find more than four of the simple 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 abrasion, and uncertainty will be occasioned in the result of the process. A longer or shorter time is required, according to the texture of the stone. Of the harder gems, 100 grains require two or three hour's 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 before and after pulverization, that the addition, if any, may be ascertained and allowed for. Gems, and stones of equal hardness, gain generally from 10 to 13 *per cent.* When a stone is extremely difficult to be reduced to powder, it may sometimes be necessary 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 acids.

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 proportion, in a gentle heat, for two or three hours. Ascertain the loss of weight, in the manner pointed out, vol. i. p. 301, 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 it bulk of water, and add a little sulphuric acid, or in preference, 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 strontites) is present, or, if both are contained in the solution, to separate them from each other, add sulphate of soda till the precipitate 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 equal 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 occasion 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 carbonate 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 acids. 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 acid, which would prevent the action of the barytic earth.[†]

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[*] The sulphuric acid is chiefly eligible for stones of the magnesian genus.

[†] 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.

(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.

(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, very cautiously, diluted muriatic acid, till the precipitate ceases, and no longer; or, as Mr. Chenevix recommends, substitute muriate of ammonia; 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, though not with perfect accuracy, 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,† crystallized sulphate of lime contains one third 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 1.850, 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 its sulphate by the sub-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.

It had been recommended, when magnesia and lime are con-

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* The bottom of a broken Florence flask answers this purpose extremely well, and bears, without breaking, the heat necessary to expel the sulphuric acid.

† Vol. i. page 76, n.

tained in the same solution, to precipitate the latter by the bi-carbonate of potash; but it has been shown by Bucholz, that this process is defective,* a considerable proportion of the carbonate of lime remaining in solution. Dobereiner prefers adding the sub-carbonate of ammonia to the cold solution of the two earths. The carbonate of lime is thus thrown down, and carbonate of magnesia may afterwards be separated, by boiling the liquor: or, both carbonates may be precipitated together by adding sub-carbonate of soda or of potash to the heated solution; and from this precipitate, after being sufficiently washed, muriate of ammonia will take up the carbonate of magnesia, leaving that of lime separate. From the weights of the carbonates, it is easy to estimate those of the pure earths contained in them.

(G) If magnesia and alumine only be held in solution by an acid (the absence of lime being indicated by the non-appearance of a 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, in his Contributions, vol. i. page 418. The magnesia, remaining in solution, may be precipitated by sub-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.†

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, p. 337. 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

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* Ann. de Chim. et Phys. iii. 403.

† See sect. 1. xvii. of the chapter on Mineral Waters.

‡ 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.

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.* 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 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 451.

(I) Let 100 grains, or any other determined 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 earthenware 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 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 opaque, 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

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* See Klaproth, vol. i. pages 66 and 75.

† 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. pp. 212, 213. A platinum crucible is unfit for this purpose, as it is corroded by pure alkalies.

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. Chenevix 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 a very fine powder, and mingled with 2½ or three times its weight of glass of borax (see part i. chap. xvi.) is to be exposed to a strong heat for two hours in a crucible of platinum, set in a larger 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 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, i. 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 should ensue 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, in part i. 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.) 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.

To separate the oxides of iron and manganese from each other, Gehlen recommends succinic acid, which is preferred, also, by Klaproth and Bucholz. Berzelius employs for this purpose the compounds of benzoic acid. Dr. John advises the addition of oxalate of potash to the solution of the two oxides, first rendered as neutral as possible; but Bucholz finds that this process is imperfect, and that the oxalates precipitate manganese as well as iron. Mr. Hatchett has suggested another method of separating iron from manganese. The solution of the ore, made by muriatic acid, and filtrated, must be diluted with three or four pints of cold distilled water. To this liquid, pure ammonia must be gradually added, till it slightly restores the blue colour of reddened litmus paper. The oxide of iron will thus be separated, and will remain on the filter upon which the liquor is thrown; and the oxide of manganese will pass through it, in a state of solution. The oxide of manganese may be obtained by evaporation to dryness, and by calcining in a heat sufficient to expel the muriate of ammonia.*

(*d*) Magnesia and oxide of manganese may be separated by adding to their solution (*c*) the hydro-sulphuret of potash,† 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

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* Thomson's Annals, v. 343.

† See vol. i. page 370.

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 the solution evaporated to dryness. Liquid ammonia is then to be added, which acts on the oxide of nickel only. The solution may be again evaporated to dryness, which will render the oxide of iron more dense, and more easily separable from the soluble portion. A fresh addition of ammonia will now readily dissolve the nickel, leaving the oxide of iron, which must be collected on a filter, 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.†

(*g*) Oxide of nickel may be separated from oxide of copper, when contained in the same solution, by immersing in the solution a bar of zinc, which will precipitate the latter metal only. (*h*) From the ammoniacal solution of nickel and cobalt, Mr. Phillips finds that the former metal is immediately precipitated by potash or soda, which very slowly and sparingly throw down cobalt from the same solvent.

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 mine-

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* Dr. Marcet alleges that after this operation, the iron still remains in the state of peroxide. Geolog. Transact. i.

† For an example of the separation of nickel from iron, see Klaproth's Contributions, vol. i. page 422, where, also, and page 428, is an instance of the testing of nickel for copper.

ralogist, 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 potash, and a sufficient quantity of distilled water. The acid, united with the earth, will quit it and pass to the potash, while the carbonic 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 occurrence. 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 separated, but the glucine, being soluble in the carbonate of ammonia, remains dissolved, and may be precipitated by boiling the solution.

(U) Zircon may be separated from alumine, by boiling the mixed earths with pure soda, which acts only on the latter.* From an acid solution containing both earths, the alumine is thrown down by saturated carbonate of potash, which, when added in excess, redissolves 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 precipitate 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 precipitate will ensue, consisting of alumine, with some yttria. To separate the latter earth, dissolve in muriatic acid, and add an excess 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 discovered in some stones) may be detected by boiling the powdered mineral,

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* Klaproth, vol. ii. page 213.

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 supersaturated with sulphuric acid. Evaporate to dryness, redissolve 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 character, vol. i. page 247.

Soda was first found, by Klaproth, in chrysolite, in the large proportion 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 alkalies 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 (263); and, accompanied by soda, in pumice (20.)

A new method has been proposed by Sir H. Davy,[*] for analyzing stones, containing either of the fixed alkalies; *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 a 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 ounce and half or two ounces.

If the stone contain silex, this earth will be separated in the process of solution and evaporation. It must be collected on 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 it tastes strongly sour, and evaporated 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.

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[*] Philosophical Transactions, 1805; or Nicholson's Journal, xiii. 86.

SECTION V.

Analysis of Inflammable Fossils.

THE exact analysis of inflammable fossils is seldom necessary in directing the most benefical 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 preceding 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.*

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 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 ac-

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* See his Elements of Mineralogy, vol. ii. page 514.

tion 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 platinum; 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 platinum*, 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 platinum will be indicated by a precipitate, on adding a solution of muriate of ammonia. When gold and platinum are both contained in the same solution, they may be separated from each other by the last-mentioned solution, which throws down the platinum, but not the gold. In this way platinum 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 contain 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. page 54, 541, &c.; and also from Mr. Chenevix's paper on the analysis of arseniates of copper and iron, Philosophical Transactions, 1801, or Nicholson's Journal, 8vo. vol. i.; and from Vauquelin's remarks in Thomson's Annals, iv. 157.

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 vinegar 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 deposit, 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 mu-

riatic 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.*

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.†

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, evaporate the solution; after which, a farther addition of water will precipitate the remainder.‡

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 grayish 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.§

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* See Klaproth on the Analysis of Antimoniated Silver Ore, vol. i. p. 560.

† See Chenevix, Philosophical Transactions, 1801, page 215.

‡ 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, page 220, c.

§ See chap. xix. sect. 17.—An example of the analysis of an ore of cobalt may be seen in Klaproth, vol. i. page 554; 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.*

Ores of manganese may also be distinguished by the colour they impart to borax, when exposed together to the blow-pipe.†

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

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* See the analysis of an ore of manganese, *viá humidá*, in Klaproth, vol. i. page 510; and of a cobaltic ore of manganese, page 569.

† See chap. xix. sect. 18; and also Thomson's Annals, iii. 312.

nitric acid, and may thus be 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.*

Respecting the ores of the remaining metals, sufficient information has been already given for the purposes of the general student, in part i. chap. xix. 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. is absolutely necessary. These have already been enumerated in the chapter on Apparatus, and will be found described in the Explanation of the Plates. Much useful information respecting the composition of minerals may, also, be gained from experiments with the blow-pipe. The most ample directions for assays of this kind are given in a Memoir by Haussman, in the 43d volume of the Philosophical Magazine, and by Gahn in the 11th vol. of Dr. Thomson's Annals, p. 40.

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

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* See Hatchett's Analysis of the Carinthian Molybdate of Lead, Philosophical Transactions, 1796; and Klaproth, vol. i. pages 534, 538.

formed, may be washed off, and the oxide must be reserved for subsequent experiments.

As many of the metals retain their oxgen 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 to a Treatise on the General Principles of Chemical Analysis, translated from the French of Thenard, by Mr. Merrick. Various excellent examples, which may be studied with great advantage, may be found in the essays of Vauquelin, dispersed through the Annales de Chimie; in 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 to other models of chemical skill and accuracy, conjoined with 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.

ELEMENTS

OF

EXPERIMENTAL CHEMISTRY.

PART III.

APPLICATION OF CHEMICAL TESTS AND RE-AGENTS TO VARIOUS USEFUL PURPOSES.

CHAPTER I.

METHOD OF DETECTING POISONS.

WHEN 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.

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* 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.

SECTION I.

Method of discovering Arsenic.

When 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 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 sulphureted 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.*

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 sulphureted 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 (hydrogureted sulphuret?) had been added, was almost instantly rendered completely opaque by one 80th 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 mani-

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* See vol. i. page 292.

† Edinburgh Medical and Surgical Journal, v. 166.

fested 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 that of the pigment called Scheele's green.* 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 subcarbonate 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, one 40th 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 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 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:‡

Into a clean Florence oil flask, introduce two or three grains of any powder suspected to be arsenic; add not less than eight ounce-

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* See part i. chap. xix. sect. 16. † Lib. citat. p. 170.

‡ London Medical and Physical Journal, xxiii. 448.

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.

The nitrate of silver, Mr. Hume finds, also, acts very sensibly upon *arsenate* of potash, and decidedly distinguishes this salt from the above solution or *arsenite* of potash; the colour of the precipitate, occasioned by the *arsenate*, being much darker and more inclined to brick-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.

A modified application of this test has since been proposed by Dr. Marcet, whose directions are as follow. Let the fluid, suspected to contain arsenic, be filtered; let the end of a glass rod, wetted with a solution of pure ammonia, be brought into contact with this fluid, and let the end of a clean rod similarly wetted with solution of nitrate of silver, be immersed in the mixture. If the minutest quantity of arsenic be present, a precipitate of a bright yellow colour inclining to orange will appear at the point of contact, and will readily subside to the bottom of the vessel. As this precipitate is soluble in ammonia, the greatest care is necessary not to add an excess of that alkali. The acid of arsenic, with the same test, affords a brick-red precipitate.*—Mr. Hume, it may be added, now prepares his test by dissolving a few grains, say ten, of lunar caustic in nine or ten times its weight of distilled water; precipitating by liquid ammonia; and very cautiously adding liquid ammonia, till the precipitate is redissolved, and no longer. To apply this test, nothing more is required than to dip a rod of glass into this liquor, and apply it to the surface of a solution supposed to contain arsenic, which will be indicated by a yellow precipitate.

Mr. Sylvester has objected to this test, that it will not produce the expected appearance, when common salt is present. He has, therefore, proposed the red acetate of iron as a better test of arse-

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* Med. Chir. Trans. ii. 156.

nic, with which it forms a bright yellow deposit; or the acetate of copper, which affords a green precipitate. Of the two, he recommends the latter in preference, but advises that both should be resorted to in doubtful cases.* Dr. Marcet, however, has replied, that the objection arising from the presence of common salt is easily obviated; for if a little dilute muriatic acid be added to the suspected liquid, and then nitrate of silver very cautiously till the precipitate ceases, the muriatic acid will be removed, but the arsenic will remain in solution, and the addition of ammonia will produce the yellow precipitate in its characteric form. It is scarcely necessary to add that the quantity of ammonia must be sufficient to saturate any excess of nitric acid which the fluid may contain.†

A more important objection to nitrate of silver as a test of arsenic is, that it affords, with the alkaline phosphates, a precipitate of phosphate of silver, scarcely distinguishable by its colour from the arsenite of that metal.‡ In answer to this, it is alleged by Mr. Hume,§ that the arsenite of silver may be discriminated by a curdy or flocculent figure, resembling that of fresh precipitated muriate of silver, except that its colour is yellow; while the phosphate is smooth and homogeneous. The better to discriminate these two arsenites, he advises two parallel experiments to be made, upon separate pieces of clean writing paper, spreading on the one a little of the fresh prepared arsenite, and on the other a little of the phosphate. When these are suffered to dry, the phosphate will gradually assume a black colour, or nearly so, while the arsenite will pass from its original vivid yellow to an Indian yellow, or nearly a fawn colour.

(G) But the most decisive mode of determining the presence of arsenic, (which, though not absolutely indispensable, should always be resorted to, when the suspected substance can be obtained in sufficient quantity) is by reducing it to a metallic state; for its characters are then clear and unequivocal. For this purpose, let a portion of the white sediment, collected from the contents of the stomach, be dried and mixed with three times its weight of black flux (see p. 120); 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 the 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. 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

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* 33 Nich. Journ. 306.

† Phil. Mag. xli. 124.

‡ Thomson's Annals, viii. 152.

§ Med. and Phys. Journ. Jan. 1818.

end of the tube loosely, with a little paper, and heat the sealed 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 arsenic, a white stain will be left on the copper.

(H) 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 coated 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 or 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) Sulphureted water throws down a dark-coloured sediment, which, when dried and strongly heated, is wholly volatilized, without any odour of garlic.

For the detection of corrosive sublimate, Mr. Sylvester has recommended the application of galvanism, which exhibits the mercury in a metallic state. A piece of zinc wire, or if that cannot be had, of iron wire about three inches long, is to be twice bent at right angles so as to resemble the Greek letter Π. The two legs of this figure should be distant about the diameter of a common gold wedding-ring from each other, and the two ends of the bent wire must afterwards be tied to a ring of this description. Let a plate of glass, not less than three inches square, be laid as nearly horizontal as possible; and on one side, drop some sulphuric acid, diluted with about six times its weight of water, till it spreads to the size of a halfpenny. At a little distance from this towards the other side, next drop some of the solution supposed to contain corrosive sublimate, till the edges of the two liquids join together; and let the wire and ring prepared as above be laid in such a way that the wire may touch the acid, while the gold ring is in contact with the suspected liquid. If the minutest quantity of corrosive sublimate be present, the ring in a few minutes will be covered with mercury on the part which touched the fluid.

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.

It may be proper to observe, that the failure of attempts to discover poisonous substances in the alimentary canal after death, is by no means a sufficient proof that death has not been occasioned by poison. For it has been clearly established, by experiments made on animals, that a poison may be so completely evacuated, that no traces of it shall be found, and yet that death may ensue from the inflammation which it has excited.

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. In this, and all other experiments of the same kind, the fluid should be viewed by reflected, and not by transmitted light.

II. Lead is occasionally found, in sufficient quantity to be injurious 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 sulphureted 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 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 sulphureted 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 affected by alkalies, which has been re-dissolved in nitric acid.

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* See his "Researches into the Properties of Spring Water." 8vo. London. Johnson. 1803.

(*b*) Though it forms, in other cases, no cloud, the precipitate itself becomes darkened by the sulphureted 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 sulphureted test then forms a dark cloud with the solution of the precipitate. In these experiments, it is essential that the acid, used to re-dissolve 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 certainty than the foregoing one.

The nitric acid, used in these experiments, should be perfectly pure; and the test should be recently prepared by saturating water with sulphureted 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 portions 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 sulphureted test. Sulphate of soda would be found more effectual in this process than the muriate, on account of the greater insolubility of sulphate of lead. This property, indeed, renders sulphate of soda an excellent test of the presence of lead, when held in solution by acids, for it precipitates that metal, even when present in very small quantity, in the form of a heavy white precipitate, which is not soluble by acetic acid.

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 together, into a small phial, sixteen grains of sulphuret of lime, prepared in the dry way (by exposing to a red heat, in a covered crucible, equal weights of powdered lime and sulphur, accurately mixed,) 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 subsided, 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 solution 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.*

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 hydrosulphuret of potash or of ammonia may be given; or a solution of the common sulphuret.

Mr. Sylvester has proposed the gallic acid as an excellent test of the presence of lead.†

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.‡

Oxalic acid has lately, in several instances, been taken by mistake for Epsom salt, and has invariably proved fatal. We have no experience of the best antidote to its effects; but it is probable that this would consist in the immediate administration of carbonate of magnesia, or, if neither of these be at hand, of chalk or whitening of calcined magnesia. At the same time, it will be proper to dilute the contents of the stomach by drinking copiously, and to endeavour to excite vomiting by tickling the throat with a feather. These measures should be employed with the utmost promptitude; for the deleterious action of oxalic acid appears to exceed in rapidity even that of arsenic.

CHAPTER II.

RULES FOR ASCERTAINING THE PURITY OF CHEMICAL PREPARATIONS, EMPLOYED FOR THE PURPOSES OF MEDICINE, AND FOR OTHER USES.

I.—*Sulphuric Acid,—Acidum Sulphuricum of the London Pharmacopœia,—Oil of Vitriol.*

THE specific gravity of sulphuric acid should be 1.8485, at 60° Fahrenheit; when stronger, there is reason to suspect the presence

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* Lambe, page 175.

† 33 Nicholson's Journal, 310.

‡ Systême, vol. i. page 240.

of sulphate of lead, or other impurities. It should remain perfectly transparent when diluted with distilled water. If a sediment occur, on dilution, it is a proot of the presence of sulphate of lead.

Iron may be detected in sulphuric acid, by saturating a 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, which turns it blue; and lead may be detected by the sulphuret of ammonia, which causes a black precipitate. The latter metal, however, is for the most part thrown down 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.*

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 sulpuric 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 in their most concentrated state should have the specific gravity of 1.500; but they are seldom fond so heavy.

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

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* See vol. i. page 272.

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 1.170. That of commerce is generally from 1.156 to 1.160; and the latter number denotes the strength of acid prepared according to the London Pharmacopœia.

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 1.060 at least; but, as I have already stated, its acidity does not keep pace with its density.

V.—*Acetous Acid,—Acidum Aceticum, P. L.—Distilled Vinegar.*

If vinegar be distilled in copper vessels, it can hardly fail of 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 sulphureted ammonia, or by water saturated with sulphureted hydrogen. (See the preceding chapter.) The strength of distilled vinegar ought, according to Mr. R. Phillips, to be such, that a fluid-ounce should decompose 13.8 grains of carbonate of lime.

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 1.480.

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 pure 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 the cautious addition of carbonate of potash, which forms a difficultly soluble bi-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 Subcarbonas, 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 of the sediment in pure and diluted nitric acid: the siliceous earth only will remain undissolved. Add, to one part 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 carbonate of lime.

The solution of sub-carbonate of potash *(liquor potassæ subcarbonatis, 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 barytes, to detect sulphuric acid, and afterward adding to the filtered liquor a few drops of solution of nitrate of silver, to ascertain the presence of muriatic acid; or the latter impurity will be indicated at once by a solution of sulphate of silver. 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 difficultly 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 1.150; 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 condensible 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 muriatic acids. Carbonic acid is shown by a precipitation on mixing the solution with one of muriate of lime; for this earthy salt is not precipitated by pure ammonia. The experiment should he made in a closed vial; for the volatile alkali, by exposure to the air, quickly gains carbonic acid enough to become a precipitant of calcareous solutions. The best mode of determining the strength of the solution is by taking its specific gravity, which, at 60° Fahrenheit, should be as 905, or thereabouts, to 1000. That of the London Pharmacopœia (edit. 1815) has the specific gravity of 0.960; and is, therefore, of very inferior strength.

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 pungency 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, p. 308, 309. Nor should it be mixed with earthy or metallic salts, the former of which are detected by carbonate, 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 42½ 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 precipitated by carbonate of soda, and the precipitated lime and magnesia may be separated from each other by the rules given in page 337.

XXI.—*Muriate of Ammonia,—Ammoniæ Murias, L. P.—Sal Ammoniac.*

This salt ought to be entirely volatilized, by a low heat, when laid on a heated iron. It sometimes contains sulphate of ammonia, however, which, being also volatile, cannot be thus detected. To ascertain the presence of the latter salt, add the muriate or nitrate 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 discovered by adding a solution of tartaric acid, which, if the suspected salt be present, will occasion a copious precipitate. The tartrate is also detected by its forming, with acetate of lead or muriate of barytes, a precipitate soluble in acetic or muriatic acid; and sulphates, by a precipitate with the same agents, insoluble in those acids.

XXIII.—*Neutral Tartrate of Potash,—Potassæ Tartaris, P. L.—Soluble Tartar.*

This salt should afford a very copious precipitate on adding tartarous acid. The only salt likely to be mixed with it is sulphate of soda, which may be detected by a precipitate with muriated barytes, 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 adulterated 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 frequently, and let it stand one or two hours. The sulphate of potash, being more soluble than the tartrate, will be taken up; and may be known by the bitter taste of the solution, and by a precipitate, on adding muriate of barytes, which will be insoluble in muriatic acid.

XXV.—*Compound Tartrate of Soda and Potash,—Soda Tartarizata, P. L.—Rochelle or Seignette's Salt.*

Sulphate of soda, the only salt with which this may be expected to be adulterated, is discovered by adding to a solution of Rochelle 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,—Magnesia Sulphas, P. L.—Epsom 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 precipitation 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 crystallized sulphate of magnesia give between 35 and 36 of the dry carbonate, when completely decomposed by about 57 of sub-carbonate of potash, if the salt under examination afford a considerably less proportion, its sophistication 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 sulphate of ammonia, when that of soda will remain fixed, and every 10 grains of the dry residue indicate about 22½ of crystals.

Muriate of magnesia or of lime may be detected by the salt becoming moist when exposed to the air, and by a precipitation with nitrated silver, after nitrate of barytes has separated all the sulphuric acid and magnesia, or by fumes of muriatic acid arising on the addition of a little sulphuric acid. These, if in very small quantity, will be made apparent by a stopper moistened with liquor of ammonia. Lime is discoverable by a white precipitate on the addition of liquid carbonate of ammonia.

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, prussiate of potash, and the latter by any 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 alum or fused muriate of soda. To discover these, borax must be dissolved in water, and its excess of alkali be saturated with nitric 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.*

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* Philosophical Magazine, xxxv. 236.

Glass of antimony has a rich brown or reddish 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 opaque.

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 oxymuriatic odour, and leaves much sediment.

Let a little of each solution be separately dropped into water. The true deposits 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 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 Oxymurias, P. L. Corrosive Sublimate.*

If there be any reason to suspect arsenic in this salt, the admixture, (which, however, is not likely to be practised except with the intention of its acting as a poison) 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

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* Prepared by digesting a little verdegris in the solution of pure ammonia.

may be ascertained by boiling, for a few minutes, one part of calomel with one 32d 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 powder. Lead and tin are frequent impurities, and the mercury becomes 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 sulphureted 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 acid and the addition of sulphureted 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, into 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 Rubrum, P. L.*

This substance is rarely found adulterated, as it would be difficult to find a substance well suited to this purpose. If well prepared, 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 sulphureted water, or sulphuret of ammonia, either of which produces, with the compounds of lead, a dirty dark co-

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* See Mr. Accum's valuable papers on the detection of adulterations, in Nicholson's Journal, 4to.

loured precipitate; or by adding sulphate of soda, which throws down sulphate of lead. This oxide ought to be totally volatilized by heat.

XXXVII.—*White Oxide of Mercury,—Hydrargyrus Præcipitatus 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 adding to the dilute solution a little oxalic acid.

XXXVIII.—*Red Sulphureted 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 Sulphureted 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 adding, to the acetous solution, sulphureted water, or sulphuret of ammonia. Arsenic, to which the activity of this medicine has been sometimes ascribed, is detected, also, by sulphureted 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.

XLV.—*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 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: rectified spirit of wine 835: proof spirit of 920: sulphuric æther 729; and as found in the shops under the name of *æther rectificatus* it ought not to exceed 750: the *spiritus ætheris nitrici* (P. L. 1815), or sweet spirit of nitre, 834. The æthers, when quite pure, 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 essentials to the success of chemical processes.

I.—*Mode of detecting the Adulteration of Potashes, Pearl-ashes, and Barilla.*

Few objects of commerce are sophisticated to a greater extent than the alkalies, 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. To detect these adulterations, by determining the strength of alkalies, several methods have been recommended. In the early editions of this work, I gave, as the best, that of Mr. Kirwan, described in the Transactions of the Royal Irish Academy for 1789, which consists in ascertaining the quantity of alum, decomposed by the alkali under examination. Experience, however, has since convinced me, that a better mode of making this assay is by means of sulphuric acid; the quantity of acid, required for neutralizing a given weight of the alkali under examination, being directly as the alkaline power of the latter.

An apparatus for this purpose was, several years ago, recommended by M. Descroisilles.* It consists principally of a glass

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* 60 Ann. de Chim. 77.

tube, from five to six tenths of an inch diameter, sealed at one end, and inserted at this end into a pedestal which keeps it in a perpendicular position. The upper and open extremity is a little funnel-shaped, and provided with a lip, for the convenience of pouring out fluids. On this tube is engraved a scale of 72 equal parts, the first degree being at the uppermost part of the tube, and the 72d, of course, near its sealed extremity. Each degree is intended to contain half a French gramme (the gramme being 15½ English grains very nearly) of the acid test liquor, which is formed by diluting one part by weight of sulphuric acid,* with nine parts by weight of distilled water.

As an example of the use of this alkalimeter, let us suppose that we wish to assay a sample of American pearlash. Reduce to powder a sufficient quantity of the alkali to serve as a fair average specimen; and of this, put 10 grammes (= 154.5 grains) into three or four ounces of water, either warm or cold. Let the mixture be agitated till the solution is complete, and filtered through paper.

Of the clear solution, pour one half into a common tumbler. Next, pour diluted acid into the tube to the line marked 0; and taking the tube in the left hand, add the liquor, which it contains, very slowly to the alkaline solution in the tumbler, stirring all the while with one of the wooden rods, and first using this rod, to remove the drop, which adheres to the lip of the tube. When the acid is lowered in the tube to about the 40th degree, it is proper to try if the alkali be neutralized, by taking a drop on the end of a glass or wooden rod, and applying it to the proper test papers. By doing this repeatedly, the precise point of saturation will be at length attained; and the number on the tube, corresponding with the level of the remaining acid, will show the comparative strength of the alkali. The mean strength of several varieties of potash was found to be 55, denoting that they require 55 hundredths of their weight of sulphuric acid, sp. gr. 1.842 (=53 of sp. gr. 1.849) for saturation; from which it may be calculated that they contained, *per cent.* a quantity of alkali, equal to about 75 parts of sub-carbonate of potash.

When soda or barilla is submitted to experiment, it is necessary to make the solution by means of hot water; and in all cases, it is adviseable to repeat the experiment on the half of the liquor which has been reserved.

The following table, given by M. Descroisilles, shows the strength of some alkalies of commerce, commonly met with in France. The last column I have calculated from obvious data. It expresses the quantity of subcarbonate of potash or soda, to which 100 parts of the respective alkalies of commerce are equivalent; the four last only being compared with the subcarbonate of soda.

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* Of sp. gr. 1.842; for this density, according to Vauquelin, corresponds with 66° of the *aréomètre*, at 55° Fahrenheit; (vid. 76 Ann. de Ch. 260.) The specific gravity of the dilute acid, I find by experiment, to be 1.066.

	Degrees.	= Subc. Potash or Soda.	
American pearlash, 1st sort	60 to 63	81 to 86	Per cent.
American potash in reddish masses, 1st ditto	60 to 63	81 to 86	
American pearlash, 2nd sort	50 to 55	68 to 75	
American potash in grayish masses, 2nd ditto	50 to 55	68 to 75	
White Russian potash	52 to 58	70 to 79	
White Dantzick ditto	45 to 52	60 to 79	
Blue Dantzick potash	45 to 52	60 to 79	
Alicant barilla	20 to 33	21 to 41	
Crystals of soda of commerce	36	39	
Natron (kelp?)	20 to 33	21 to 35	
Barilla and natron (kelp?) inferior	10 to 15	11 to 16	

Improved Alkalimeter and Acidimeter.

I have retained, in this edition, a description of the alkalimeter of Descroisilles, because it is probable that several of them may be in the possession of persons in this country; and because it is common in France to express the value of alkalies in degrees of that instrument. It has been very properly objected to it, by Dr. Ure of Glasgow,* that these degrees, being entirely arbitrary, do not denote the value of alkalies in a language universally intelligible; and he has proposed an instrument, which shall, at once, and without calculation, declare the true proportion of alkali in 100 parts of any specimen.

The principal deviation in the following rules, from the method of Dr. Ure, is, that while he employs sulphuric acid diluted to the same uniform degree (viz. of sp. gr. 1.060) for all the different alkalies, and consequently has a distinct scale for each, I use sulphuric acid of different degrees of strength for the different alkalies, and thus adapt one scale of equal parts to the several varieties of alkaline substances. Any tube of sufficient capacity, in my method of proceeding, will answer the purpose; but the most convenient size I find to be about nine inches and a half long, and three quarters of an inch inside diameter. The tube should be formed with a lip for the convenience of pouring, and be provided with a glass foot to support it (see plate ii. fig. 28.) A tube of this kind holds 1000 grains of water, and, (which is desirable) a little more. To graduate it, weigh into it 100 successive portions of distilled water at 60° Fahrenheit, of ten grains each; or, if the tube be of equal bore throughout, it may be sufficient to weigh into it ten successive portions of water of 100 grains each, dividing each of the intermediate spaces into ten parts by a pair of compasses. When 1000 grains of water have been weighed into the tube, a

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* In an Essay on Alkalimeter, which he was so good, about two years ago, as to communicate to me in manuscript, and which, I believe, he has not yet published.

line may be drawn with a file, which may be marked 0, the tenth below this 10, and so on as shown in fig. 28.

The test acid, which I prefer, is made by diluting one part of oil of vitriol of commerce of sp. gr. 1.849, with four parts of water; consequently one fifth part of its weight is concentrated oil of vitriol, and its specific gravity is, as nearly as possible, 1.141. Acid of this strength does not, on farther dilution, give out any heat, that can be a source of inaccuracy.

When an alkali is to be examined, find by Dr. Wollaston's Scale of Equivalents, how many grains of oil of vitriol are required to neutralize 100 grains of what may be considered the proper alkaline ingredients of the substance in question. This, in *pearlash*, is sub-carbonate of potash; in *potash*, pure potash; in *barilla*, or *kelp*, dry sub-carbonate of soda. Let us take pearlash as an example. On referring to the scale, we find that 100 grains of sub-carbonate of potash are equivalent to 71 grains of concentrated oil of vitriol.* Put, therefore, into the test tube a quantity of the dilute acid containing 71 grains of concentrated acid, viz. 355 grains; and to spare the trouble, on any future occasion, of weighing the acid, let a line be drawn with a file on the blank side of the tube, at the level of the acid liquor, which may be marked *Equiv. of Subc. Pot.*

Fill up the tube with water to the line marked 0, and mix the acid and and water completely by pouring them into a lipped glass vessel; stirring with a glass rod; and then returning them into the tube. Now as the whole 100 measures contain a quantity of oil of vitriol equivalent to 100 grains of sub-carbonate of potash, it is obvious that each measure of the liquor in the tube is adequate to the neutralization of one grain of the sub-carbonate.

Let 200 grains, taken out of a fair average specimen of the pearlash to be examined, be dissolved in two ounce measures of warm distilled water, filter the solution; and wash the filter with two ounces more of water, which is best applied to the margin of the paper, by means of the dropping bottle, fig. 25, *a*. Add the washings to the solution; and having mixed the whole together, pour one half into a tumbler or goblet, reserving the other half for a repetition of the experiment if necessary.

To the liquor in the glass goblet, add the diluted acid very gradually, making the additions more and more slowly towards the last. As soon as the point of neutralization is attained, which will be shown by the cessation of a change of colour in slips of litmus and of turmeric paper dipped, from time to time, into the liquor, no more acid must be added. It is proper, however, the operator should be aware, that there will often be an apparent excess of test acid, in consequence of the cabonic acid, which is disengaged, acting on the litmus paper. To avoid this source of error, it is adviseable, towards the last, to warm the liquor by setting the glass

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* Dr. Ure makes it 70.4. Journ. of Science, iv. 119.

containing it for half an hour near the fire, and while thus warmed, to add very cautiously the rest of the acid required for saturation. This point being attained, the number on the test tube, at the level of the acid remaining in it, shows at once, without any calculation, how much *per cent.* of sub-carbonate of potash is contained in the pearlash under examination. In the samples, I have tried, it has generally been about 80 *per cent.*

In operating on barilla, kelp, or any variety of the mineral alkali, the process is exactly the same, except that as 93* of oil of vitriol are equivalent to 100 of sub-carbonate of soda, we must take $93 \times 5 = 465$ grains, of sulphuric acid of density 1.141. This may be marked on the tube, *Equiv. of Subc. Soda.* In a similar manner, we may mark on the tube the equivalent of *pure potash*, *viz.* 520 grains of the above diluted acid; and that of *pure soda*, 783 grains; with any other equivalents, that may be likely to be of use.

Having ascertained the proportion of sub-carbonate of potash in any sample of pearlash, it is easy to find, by the sliding scale, its equivalent quantity of pure or caustic potash. Thus, supposing the pearlash to contain 80 *per cent.* of sub-carbonate, that number being set to sub-carbonate of potash on the scale, the equivalent in pure potash is at once seen to be 55.

To determine, by the same graduated tube, the strength of *any acid* whose equivalent is known, (which is the reverse of the foregoing process) we may put 100 grains of the acid, with a sufficient quantity of water, into a goblet; and use, for saturating it, its equivalent of any alkali. For example, 100 grains of concentrated oil of vitriol requiring for saturation 108 grains of dry sub-carbonate of soda, dissolve the latter quantity of alkali in water sufficient to make up 100 measures of solution in the tube; then pour the alkaline solution to the acid liquor, till the latter is neutralized; and the number of measures, which have been expended, exactly denote the strength of the acid.

It may sometimes be desirable to know the proportion, not of concentrated or of real acid, but of acid of some inferior degree of density, in a specimen of acid. The method of doing this will best be explained by an example. Suppose that we wish to know the equivalent, in muriatic acid of sp. gr. 1.160, to 100 grains of the same acid of sp. gr. 1.074; find, by the alkaline test, or by referring to the tables in the Appendix, how much real acid 100 grains of both those acids contain. In acid of sp. gr. 1.160, it will be 23.4 *per cent.;* in acid of sp. gr. 1.074, it will be 11. Then 23.4 : 100 :: 11 : 47. Therefore 47 grains of muriatic acid, of sp. gr. 1.160, are equivalent, in acidity, to 100 of sp. gr. 1.074.

No chemical operation can be more simple, or more easily managed, than the measurement of the strength of alkalies by acid liquors, and of acids by alkaline ones, in the way which has been

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* According to Dr. Ure, 91.4 is the true equivalent. Journ. of Science, &c. iv. 119.

described. The test-tube, which is the only instrument, required for that purpose, may be had at any glass-house, and may easily be graduated by any person who will take the necessary pains. When once accurately prepared, it will be found, also, useful for a variety of other purposes, which will readily present themselves to the practical chemist.

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 principal defect of manganese arises from the admixture of chalk, which is not always an intentional adulteration, but is sometimes found along 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 free from chalk, 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,* it appears that oxides of iron and manganese are separable by nitrous acid with the addition of sugar, which takes up the manganese only.

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* Essays, vol. i. page 572.

CHAPTER IV.

APPLICATION OF CHEMICAL TESTS TO THE USES OF THE FARMER AND COUNTRY GENTLEMAN.

The benefits that might be derived from the union of chemical skill, with the extensive observation of agricultural facts, are, perhaps, incalculable. At present, however, the state of knowledge among farmers is not such as to enable them to reap much advantage 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 offer 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 circumstances. Hence a species of lime may be extremely well adapted for one kind of land and not for another. All that can be accomplished by chemical means is to ascertain the degree of purity 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 dissolved 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 sediment with farther portions of water, and pour it upon a filter, previously weighed. Dry the filter and ascertain its increase of weight, which will indicate how much insoluble matter the quantity 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 lime-stone 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 Breedo and Matlock, in Derbyshire, and in various other parts of England.*

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,

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* See Phillips's Geology of England and Wale; page 80.

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 flash, place them in a scale, and let them be balanced. Then reduce a few ounces of dry marl into 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 lime submitted to experiment contained.

APPENDIX,

CONSISTING OF

VARIOUS USEFUL TABLES.

No. I.

CORRESPONDENCE BETWEEN ENGLISH AND FOREIGN WEIGHTS AND MEASURES.

I.—*English Weights and Measures.*

Troy Weight.

Pound.	Ounces.	Drms.	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.	Drms.	Grains.	Grammes.
1	16	256	7000.	453.25
	1	16	437.5	28.328
		1	27.34375	1.7705

Measures.

Gal.	Pints.	Ounces.	Drms.	Cub. Inch.	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.

The wine gallon contains 58176 Troy grains; and the wine pint 7272 Troy grains.

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, drachm, 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 - - - - - - - - - - - - - - - - -	1.2189
To reduce English troy grains to Paris grains multiply by - - - - - - - - - - - - - - - - -	
To reduce Paris ounces to English troy, divide by -	1.015734
To reduce English troy ounces to Paris, multiply by	

Or the conversion may be made by means of the following tables:

1.—*To reduce French to English Troy Weight.*

The Paris pound	=	7561	English troy grains.
The ounce	=	472.5625	
The gros	=	59.0703	
The grain	=	.8204	

2.—*To reduce English Troy to Paris Weight.*

The English troy pound of 12 ounces - - - - - - -	=	7031.	Paris grains.
The troy ounce - - - - -	=	585.0833	
The drachm of 60 grains -	=	73.1354	
The penny weight or denier of 24 grains - - - - - - -	=	29.2541	
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 grains.
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 - - - - - - - - - - - - - -	

Te 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	English inches.
The inch - - - - - - - - -	=	1.0664	
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	Paris inches.
The inch - - - - - - - - -	=	.9383	
The 1-8th of an inch - - - - -	=	.1173	
The 1-10th of an inch - - - -	=	.0938	
The 1-13th of an inch - - - -	=	.0782	

6.—*To reduce French Cube Measure to English.*

The Paris cube foot - - -	=	1.211278	English cubical feet, or	2093.088384	in.
The cubic inch	=	.000700		1.211378	

7.—*To reduce English Cube Measure to French**.

The English cube foot, or 1728 cubical inches -	=	1427.4864	French cubical inches.
The cubical inch - - -	=	.8260	
The cube tenth - - -	=	.0008	

§ III —MEASURE OF CAPACITY.

The Paris pint contains 58.145† English cubical inches, and the English wine pint contains 28.875 cubical inches; or the Paris pint

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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 Baumé, 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.

contains 2.0171082 English pints, and the English pint contains .49617 Paris pints; hence,

To reduce the Paris pints to the English, multiply by - - - - - - - - - - - - - -	2.0171082
To reduce the English pints to the Paris, divide by - - - - - - - - - - - - - - - -	

The septier of Paris is 7736 French, or 9370.45 English cubical inches; and the muid is 92832 French, or 912445.4 English cubical inches.

VI.—*Table showing the Comparison between French and English Grains.* (Poid de Marc.)

French grs. =	English grs.
* 1	0.8203
2	1.6407
3	2.4611
4	3.2815
5	4.1019
6	4.9223
7	5.7427
8	6.5631
9	7.3835
10	8.203
20	16.407
30	24.611
40	32.815
50	41.019
60	49.223
70	57.427
80	65.631
90	73.835
100	82.03
200	164.07
300	246.11
400	328.15
500	410.19
600	492.23
700	574.27
800	656.31
900	738.35
1000	820.3
2000	1640.7
3000	2461.1
4000	3281.5
5000	4101.9
6000	4922.3
7000	5742.7
8000	6563.1
9000	7383.5
* 10.000	8023.0

English grs. =	French grs.
1	1.2189
2	2.4378
3	3.6568
4	4.8757
5	6.0947
6	7.3136
7	8.5325
8	9.7515
9	10.9704
10	12.189
20	24.378
30	36.568
40	48.757
50	60.947
60	73.136
70	85.325
80	97.515
90	109.704
100	121.89
200	243.78
300	365.68
400	487.57
500	609.47
600	731.36
700	853.25
800	975.15
900	1097.04
1000	1218.9
2000	2437.8
3000	3656.8
4000	4875.7
5000	6094.7
6000	7313.6
7000	8532.5
8000	9751.5
9000	10970.4
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.	
French. =	English.
1	1.2136
2	2.4272
3	3.6408
4	4.8544
5	6.0681
6	7.2817
7	8.4953
8	8.7089
9	70.9225
10	12.136
20	24.272
30	36.408
40	48.544
50	60.681
60	72.817
70	84.953
80	97.089
90	109.225
100	121.36
200	342.72
300	364.08
400	485.44
500	606.81
600	728.17
700	849.53
800	970.89
900	1092.25
1000	1213.6
2000	2427.2
3000	3640.8
4000	4854.4
5000	6068.1
6000	7281.7
7000	8495.3
8000	9708.9
9000	10922.5
10.000	12156.0

Cubic Inches.	
English. =	French.
1	0.8239
2	1.6479
3	2.4719
4	3.2958
5	4.1198
6	4.9438
7	5.7677
8	6.5917
9	7.4157
10	8.239
20	16.479
30	24.719
40	32.958
50	41.198
60	49.438
70	57.677
80	65.917
90	74.157
100	82.39
200	164.79
300	247.19
400	329.58
500	411.98
600	494.38
700	576.77
800	659.17
900	741.57
1000	823.9
2000	1647.9
3000	2471.9
4000	3295.8
5000	4119.8
6000	4943.8
7000	5767.7
8000	6591.7
9000	7415.7
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.		*English.*			
				Tons.	Hogs	Wine G.	Pints.
Millilitre	=	.06103					
Centilitre	=	.61028					
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.		*Avoirdupois.*		
				Poun.	Oun.	Drm.
Milligramme	=	.0154				
Centigramme	=	.1544				
Decigramme	=	1.5444				
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

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* Recently determined by Captain Kater to be 39.37079 inches. (Phil. Trans. 1818, p. 109.)

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	1567.000	1898.000

X.—*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 : 29 :: 97.92 : 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 : 50 :: 100 : 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 : 30 :: 50 : 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 : 30 :: 49 : 50.7

One hundred inches, therefore, would weigh 50.7 grains.

XI. *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 - -	2.6873	Alabaster, oriental - -	2.7302
Emerald, from Peru -	2.7755	Carnelian - - - - -	2.6137
Crysolithe, from Brasil -	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.

	Hassenfratz.	Kirwan.	Muschenbrock.	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	
Supertartrate 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	

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* 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.

GLASSES AND VITRIFICATIONS.	Specific Grav.
Green bottle-glass	2.7325
French crystal-glass	2.8922
French mirror-glass, from St. Gobin	2.4882
English flint-glass	3.3203
China porcelain	2.3847
INFLAMMABLES.	
Roll-sulphur	1.9907
Phosphorus	1.714
Pit-coal	1.3292
Amber	1.0780
Heaviest charcoal	0.441
Mineral Naphtha	0.708
Camphor	0.9887
Liquid ammonia	0.8970
WATERS.	
Distilled water	1.0000
Sea water	1.0263
Water from the Asphaltic Sea	1.2403
ACIDS.	
Sulphuric acid of commerce	1.8500
Sulphuric acid, real	2.1250
Nitric acid	1.5800
Muriatic acid	1.1940
Concentrated acetic acid	1.0626
SPIRITUOUS LIQUIDS.	
Madeira wine	1.0382
Cyder	1.0181
Brown beer	1.0338
Burgundy wine	0.9915
Champagne wine	0.962
Brandy	0.8371
Alcohol*	0.8293
Nitric ether	0.9088
Acetic ether	0.8664
Sulphuric ether†	0.7396
Muriatic ether	0.7296

	Specific Grav.
ETHEREAL OILS.	
Oil of cinnamon	1.0439
Oil of cloves	1.0363
Oil of lavender	0.8938
Spirit of turpentine	0.8697
FAT OILS.	
Linseed oil	0.9403
Poppy oil	0.9288
Oil of sweet almonds	0.9170
Olive oil	0.9153
ANIMAL FLUIDS.	
Asses' milk	1.0355
Cows' milk	1.0324
Human milk	1.0203
Human urine	1.0106
ANIMAL FATS.	
Spermaceti	0.9433
Butter	0.9423
Tallow	0.9419
Mutton suet	0.9235
Train oil	0.9235
Hogs' lard	0.9568
Ivory	1.825
Bees' wax	0.9648
GUMS.	
Common gum	1.4817
Gum Arabic	1.4523
Gum tragacanth	1.3161
GUM RESINS.	
Asafœtida	1·3275
Scammonium, from Smyrna	1.2743
Galbanum	1.2120
RESINS.	
Guaiacum	1.2289
Jalap	1.2185
Ammoniacum	1.2071
Benzoe	1.0924

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* *Per* Chaussier 0.7980.

† *Per* Lovitz 0.6320.

Table of Specific Gravities of Solid and Liquid Substances,—Continued

	Specific Grav.		Specific Grav.
RESINS.		WOODS.	
Sandaric	1.0920	Mahogany	1.063
White resin	1.0819	Olive tree	0.9270
Colophony	1.0441	Mulberry tree, Spanish	0.8970
Mastich	1.0742	Beech tree	0.8520
Copal, transparent	1.0452	Yew tree, Spanish	0.8070
Elastic resin	0.9335	Apple tree	0.7930
		Plum tree	0.7850
INSPISSATED JUICES.		Maple tree	0.7550
Aloe *succotrina*	1.3795	Cherry tree	0.7150
Opium	1.3366	Quince tree	0.7050
		Orange tree	0.7050
WOODS.		Walnut tree	0.6710
Lignum guaiacum	1.3330	Pear tree	0.6610
Box wood, Dutch	1.3280	Cypress, Spanish	0.6440
French box wood	0.912	Pine tree	0.5500
Ebony	1.2090	White Spanish poplar tree	0.5294
Heart of old oak	1.1700	Cork	0.2400

XII.—*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.

XIII.—*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	.861	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		

No. II.

ADMEASUREMENT AND EFFECTS OF HEAT.

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 or muriate of soda, it was made the zero. Hence the freezing point became 32°, and the boiling point 212°.

The Centrigrade 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 $180^\circ\ \text{F.} = 100^\circ\ \text{C.} = 80^\circ\ \text{R.} = 150^\circ\ \text{D} = \frac{18}{13}\,\text{W}$.

I. To reduce centrigrade degrees to those of Fahrenheit, multiply by 9 and divide by 5, and to the quotient add 32, that is, $\frac{\text{C.} \times 9}{5} + 32 = \text{F.}$

2. To reduce Fahrenheit's degrees to centrigrade $\frac{\text{F} - 22 \times 5}{9} = \text{C.}$

3. To reduce Reaumur's to Fahrenheit's, we have the following formula, $\frac{\text{R.} \times 9}{4} + 32 = \text{F.}$

4. To convert Fahrenheit to Reaumur, $\frac{\text{F.} - 32 \times 4}{9} = \text{R.}$

6. To reduce De Lisle's degrees under the boiling point, we have $\text{F.} = 212 - \frac{\text{D.} \times 6}{5}$. To reduce those above the boiling point, $\text{F.} = 212 + \frac{\text{D.} \times 6}{5}$.

6. And, inversely, to reduce Fahrenheit's degrees to De Lisle's, under the boiling point, $\frac{1060 - 5\ \text{F.}}{6} = \text{D.}$; above the boiling point, $\frac{\text{F.} \times 5 - 1060}{6} = \text{D.}$

7. To reduce Wedgwood's degrees to those of Fahrenheit, we have $W. \times 130 + 1077 = F.$

8. Inversely, to reduce Fahrenheit to Wedgwood, $\frac{F. - 1077}{130} = W.$

Table showing the Correspondence between the Degrees of Fahrenheit's Thermometer and the new Scale of Mr. Dalton.
(See vol. i. p. 81.)

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	178.	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 (Thompson)
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 (Thompson)

2.—*Melting Points of Solids.*

40	Equal parts of sulphur and phosphorus
82	Adipocire of muscle
97	Lard (Nicholson)
90	Phosphorus
104	Resin of bile
109	Myrtle wax (Cadet)
112	Spermaceti (Bostock)
127	Tallow (Nicholson) 92 (Thompson)
149	Bees' wax
145	Ambergris (La Grange)
155	Bleached wax (Nicholson)
212	Bismuth 5 parts, tin 3, lead 2

Fahren.	Wedg.	
234		Sulphur (Hope) 212 (Fourc.) 185 (Kirw.)
235		Adipocire of biliary calculi (Fourcroy)
383		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

Fahren.	Wedg.	
476		Bismuth (Irvine)
612		Lead (Chrichton) 594 (Irv.) 540 (Newton)
680		Zinc
809		Antimony
3809	21	Brass
4587	27	Copper
4717	22	Silver
5237	32	Gold
17977	130	Cobalt
20577	150	Nickel
21097	154	Soft nails
21637	158	Iron
21877	160	Manganese
23177	+170	Platinum, tungsten, molybdena, uranium, titanium, &c.

3. *Solids and Liquids volatilized.*

Fahren.	Wedg.	
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° (Dalton)
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.*

Fahren.	Wedg.	
— 90		Greatest cold produced by Mr. Walker
50		Natural cold produced at Hudson's Bay
23		Observed on the surface of the snow at Glasgow, 1780
14		At Glasgow, 1780
0		Equal parts, snow and salt
+ 43		Phosphorus burns slowly

Fahren.	Wedg.	
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
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 day light
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 Proney's Architecture Hydraulique.)

Temperature.	Force in English Inches of Mercury.
32	0
42	.08
52	.21
62	.38
72	.58
82	.87
92	1.26
102	1.74
112	2.37
122	3.16
132	4.16
142	5.43
152	7.00
162	9.07
172	11.0
182	14.9
192	18.7
202	23.7
212	29.8
222	37.4
232	46.5
242	57.3
252	69.7
262	83.6
272	97.1
282	108.

IV.—*Table of the Expansion of Air by Heat.*

(By Mr. Dalton.)

Fahren.		Fahren.		Fahren:	
32	1000	59	1064	86	1123
33	1002	60	1066	87	1125
34	1004	61	1069	88	1128
35	1007	62	1071	89	1130
36	1009	63	1073	90	1132
37	1012	64	1075	91	1134
38	1015	65	1077	92	1136
39	1018	66	1080	93	1138
40	1021	67	1082	94	1140
41	1023	68	1084	95	1142
42	1025	69	1087	96	1144
43	1027	70	1089	97	1146
44	1030	71	1091	98	1148
45	1032	72	1093	99	1150
46	1034	73	1095	100	1152
47	1036	74	1097	110	1173
41	1038	75	1099	120	1194
49	1041	76	1101	130	1215
50	1043	77	1104	140	1235
51	1045	78	1106	150	1255
52	1047	79	1108	160	1275
53	1050	80	1110	170	1295
54	1052	81	1112	180	1315
55	1055	82	1114	190	1334
56	1057	83	1116	200	1354
57	1059	84	1118	210	1372
58	1062	85	1121	212	1376

V.—*Table of the Expansion of Liquids by Heat.*

Temp.	Mercury.	Linseed Oil.	Sulphuric Acid.	Nitric Acid.	Water.	Oil of Turpen-	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	103778	101404	103421	- - -
130	101017	- - -	102097	104352	- - -	103954	- - -
140	101119	- - -	102320	105132	- - -	103573	- - -
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° Fahrenheit.	100236	122° Fahrenheit.	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		

VIII.—*Table of the Expansion of Solids by Heat.*

Temp.	Platinum.*	Antimon.	Steel.	Iron.	Cast Iron.	Bismuth.
32°	120000	120000	120000	120000	120000	120000
12	120104	120130	120147	120151		120167
White heat †	. . .	. . .	123428	121500	122571	
	Copper.	Cast Brass.	Brass Wire.	Tin.	Lead.	Zinc.
32°	120000	120000	120000	120000	120000	120000
212	120204	120225	120232	120298	120344	120355
	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	120274	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

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* Borda.

† Rinman.

‡ 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 5 parts Nitrate of potash - - 5 Water - - - - - - 16	From + 50° to + 10°	40
Muriate of ammonia 5 parts Nitrate of potash - - 5 Sulphate of soda - - 8 Water - - - - - - 16	From + 50° to + 4°	46
Nitrate of ammonia - 1 part Water - - - - - 1	From + 50° to + 4°	46
Nitrate of ammonia - 1 part Carbonate of soda - 1 Water - - - - - - 1	From + 50° to — 7°	57
Sulphate of soda - - 3 parts Diluted nitric acid - 2	From + 50° to — 3°	53
Sulphate of soda - - 6 parts Muriate of ammonia - 4 Nitrate of potash - - 2 Diluted nitric acid - 4	From + 50° to — 10°	60
Sulphate of soda - - 6 parts Nitrate of ammonia - 5 Diluted nitric acid - 4	From + 50° to — 14°	64
Phosphate of soda - 9 parts Diluted nitric acid - 4	From + 50° to — 12°	62
Phosphate of soda - 9 parts Nitrate of ammonia - 6 Diluted nitric acid - 4	From + 50° to — 21°	71
Sulphate of soda - - 8 parts Muriatic acid - - - 5	From + 50° to 0°	50
Sulphate of soda - - 5 parts Diluted sulphuric acid 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 Muriate of soda - - 1	From any Temperature.	to — 50	*
Snow, or pounded ice 5 parts Muriate of soda - - 2 Muriate of ammonia - 1		to — 12°	*
Snow, or pounded ice 24 parts Muriate of soda - - 10 Muriate of ammonia - 5 Nitrate of potash - - 5		to — 18°	*
Snow, or pounded ice 12 parts Muriate of soda - - 5 Nitrate of ammonia - 5		to — 25°	*
Snow - - - - - - 3 parts Diluted sulphuric acid 2	From + 32° to — 23°		55
Snow - - - - - - 8 parts Muriatic acid - - - 5	From + 32° to — 27°		59
Snow - - - - - - 7 parts Diluted nitric acid - 4	From + 32° to — 30°		62
Snow - - - - - - 4 parts Muriate of lime - - 5	From + 32° to — 40°		72
Snow - - - - - - 2 parts Chryst. muriate of lime 3	From + 32° to — 50°		82
Snow - - - - - - 3 parts Potash - - - - - - 4	From + 82° to — 51°		83

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 - Nitrate of ammonia - Diluted nitric acid -	5 parts 3 4	From 0° to — 34°	34
Phosphate of soda - Nitrate of ammonia - Diluted mixed acids -	3 parts 2 4	From — 34° to — 50°	16
Snow - - - - - - Diluted nitric acid -	3 parts 2	From 0° to — 46°	46
Snow - - - - - - Diluted sulphuric acid Diluted nitric acid -	8 parts 3 3	From — 10° to — 56°	46
Snow - - - - - - Diluted sulphuric acid	1 part 1	From — 20° to — 60°	40
Snow - - - - - - Muriate of lime - -	3 parts 4	From + 20° to — 48°	68
Snow - - - - - - Muriate of lime - -	3 parts 4	From + 10° to — 54°	64
Snow - - - - - - Muriate of lime - -	2 parts 3	From — 15° to — 68°	53
Snow - - - - - - Chryst. muriate of lime	1 part 2	From 0° to — 66°	66
Snow - - - - - - Chryst. muriate of lime	1 part 3	From — 40° to — 73°	33
Snow - - - - - - Diluted sulphuric acid	8 parts 10	From — 68° to — 91°	23

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 Specific Heats, from Mr. Dalton's New System of Chemical Philosophy*, Part I.

GASES.	Eq. Wts.	Eq. Blks.	SOLIDS.	Eq. Wts.	Eq. Blks.
Hydrogen	21.40	.002	Ice	.90 ?	.83
Oxygen	4.75	.006	Dried woods, and other vegetable substances, from .45 to	.65	
Common air	1.79	.002			
Carbonic acid	1.05	.002			
Azotic	.79	.001			
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 (2.17)	.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
Venus 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 p.	.52	.80			
Muriatic acid (1.153)	.60	.70	Oxides of the metals surpass the metals themselves, according to Crawford.		
Acetic acid (1.056)	.66	.70			
Sulphuric acid (1.844)	.35	.65			
Alcohol (.85)	.76	.65			
Alcohol (.817)	.70	.57			
Sulphuric ether (.76)	.66	.50			
Spermaceti oil (.87)	.52	.45			
Mercury	.04	.55			

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	0.9	50.
SALTS.		
Acetate of ammonia	Very soluble	
barytes	do.	
lime	do.	
magnesia	do.	
potash	100.	
soda	Very soluble	
strontites		40.

Table of the Solubility of Salts in Water,—Continued.

NAMES OF SALTS.	Soluble in 100 Parts Water.	
	At 60°	At 212°
SALTS.		
Carbonate of ammonia - - -	+30.	100.
barytes - - - -	Insoluble	
lime - - - - -	do.	
magnesia - - -	2.	
potash - - - -	25.	83.
soda - - - - -	50.	+ 100.
strontites - - -	Insoluble	
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	

Table of the Solubility of Salts in Water,—Continued.

NAMES OF SALTS.	Solubility in 100 Parts Water.	
	At 60°	At 212°
SALTS.		
Phosphate of potash - - - -	Very soluble	
soda - - - - - -	25.	50.
strontites - - -	0.	0.
Phosphite of ammonia - - -	$50.\frac{1}{4}$	+ 50.
barytes - - - - -	0.	
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.
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 - - -	$1.\frac{2}{3}$	$3.\frac{1}{2}$
Tartrate of potash - - - - -	25.	
and soda - -	20.	
antimony and potash	6.6	33.

II.—*Table of Substances soluble in Alcohol.*

NAMES OF SUBSTANCES.	Temperature.	100 Parts Alcohol 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	54½°	100.
copper	176°	100.
iron	176°	100.
lime	do.	100.
magnesia	do.	547.
mercury		88.3
zinc	54½°	100.
Nitrate of ammonia	176°	89.2
alumine	54½°	100.
cobalt	54½°	109.
lime		125.
potash	176°	2.9
silver	do.	41.7
Succinic acid	do.	74.
Sugar, refined	do.	24.½
Super-oxalate of potash		3.
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 subborate 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.—*Dr. Wollaston's Numerical Table of Chemical Equivalents.*

N. B.—Dr. Wollaston's numbers represent the weights of the atoms of bodies, oxygen being taken as unity. To reduce them to Mr. Dalton's, multiply by 7 and divide by 10; and to reduce them to the standard adopted in this Work, multiply by 7.5, and divide by 10.

1.	Hydrogen	1.32
2.	Oxygen	10.00
3.	Water	11.32
4	Carbon	7.54
5.	Carbonic acid (+ 20 oxygen)	27.54
6.	Sulphur	20.00
7.	Sulphuric acid (+ 30 oxygen)	50.00
8.	Phosphorus	17.40
9.	Phosphoric acid (+ 20 oxygen)	37.40
10.	Azote or Nitrogen	17.54
11.	Nitric acid (+ 50 oxygen)	67.54
12.	Muriatic acid dry	34.10
13.	Oxymuriatic acid (+ 10 oxygen)	44.10
14.	Chlorine 44.10 + 1.32 hy. = muriatic acid gas	45.42
15.	Oxalic acid	47.0
16.	Ammonia	21.5
17.	Soda	39.1
18.	Sodium (— 10 oxygen)	29.1
19.	Potash	59.1
20.	Potassium (—10 oxygen)	49.1
21.	Magnesia	24.6
22.	Lime	35.46
23.	Calcium (— 10 oxygen)	25.46
24.	Strontites	69.00
25.	Barytes	97.00
26.	Iron	34.50
	Black oxide (+ 10 oxygen)	44.50
	Red oxide (+ 15 oxygen)	49.50
27.	Copper	40.00
	Black oxide (+ 10 oxygen)	50.00
28.	Zinc	41.00
	Oxide (+ 10 oxygen)	51.00
29.	Mercury	125.50
	Red oxide (+ 10 oxygen)	135.50
	Black oxide (+ 125.5 mercury)	261.00
30.	Lead	129.50
	Litharge (+ 10 oxygen)	139.50
31.	Silver	135.00
	Oxide (+ 10 oxygen)	145.00
32.	Sub-carbonate of ammonia	49.00
	Bi-carbonate (+ 27.5 carbonic acid)	76.50
33.	Sub-carbonate of soda	66.60
	Bi-carbonate (+ 27.5 C. A. + 11.3 water	105.50
34.	Sub-carbonate of potash	86.00
	Bi-carbonate (+ 27.5 C. A. + 11.3 water)	125.50
35.	Carbonate of lime	63.00
36.	——— barytes	124.50
37.	——— lead	167.00
38.	Sulphuric acid dry	50.00
39.	Do. s g. 1.850 (50 + 11.3 water)	61.30
40.	Sulphate of soda (+ 10 waters = 113.2)	202.30
41.	Sulphate of potash	109.10
42.	Sulphate of magnesia dry	74.60
	Do. Crystallized (+ 7 waters = 79.3)	153.90
43.	Sulphate of lime dry	85.50
	Crystallized (+ 2 waters = 22.64)	108.10
44.	Sulphate of strontites	119.00
45.	——— barytes	147.00
46.	——— copper (1 acid + 1 oxide + 5 water)	156.60
47.	——— iron (7 water)	173.80
48.	——— zinc (do.)	180.20
49.	——— lead	189.50
50.	Nitric acid dry	67.54
	Do. s. g. 150 (+ 2 water = 22.64)	90.20
51.	Nitrate of soda	106.60
52.	——— potash	126.60
53.	——— lime	103.00
54.	——— barytes	164.50
55.	——— lead	207.00
56.	Muriate of ammonia	66.90
57.	——— soda	73.20
58.	——— potash	93.20
	Oxymuriate of do. (+ 60 oxygen)	153.20
59.	Muriate of lime	169.60
60.	——— barytes	131.00
61.	——— lead	173.60
62.	——— silver	179.10
63.	——— mercury	170.10
64.	Sub-muriate of do. (1 acid + 1 oxygen + 2 merc.)	296.10
65.	Phosphate of lead	176.90
66.	Oxalate of lead	186.50
67.	Bin-oxalate of potash	153.00

The following are the data on which the above Table is founded:

1, 2, 3. The specific gravities of oxygen and hydrogen gases are taken on the authority of Biot and Arago; and their proportions in water at 88.286 to 11.714, which numbers are in the ratio of 10 to 1.327.

4, 5. The specific gravities of oxygen and carbonic acid gases are 1.1036 to 1.5196, or as 20 (=2 oxygen) to 27.54; and deducting the oxygen, we obtain 7.54 for the equivalent of carbon.

6. The equivalent of sulphur is inferred from Berzelius's analysis of galena, which makes the lead bear to the sulphur the proportion of 86,64 to 13.36 or of 129.5 to 20.

7. From the analysis of sulphate of barytes by Claproth, the sulphuric acid is to the barytes as 34 to 66, or as 50 to 97. Deducting 30 of oxygen, we again obtain 20 for the equivalent of sulphur.

8, 9. In phosphate of lead, according to Berzelius, the litharge is to the acid as 380.56 to 100, or as 139.5 to 37.4; and deducting from this last number 20 oxygen, we have 17.4 for the equivalent of phosphorus. The same number is deducible, also, from Rose's experiments on phosphoric acid.

10. To obtain the equivalent of azote, ammonia is assumed to consist of 1 volume of azote, and 3 of hydrogen. And as the specific gravity of hydrogen was found by Biot and Arago to be to that of azote as .07321 to .96913, these numbers will be in the proportion of 1.327 to 17.54; and 1.327 × 3 = 3.98 added to 17.54, the equivalent of azote, gives 21.52 for the equivalent of ammonia.

11. The equivalent of nitric acid is deduced from Richter's analysis of nitrate of potash,* which makes the potash to the acid as 46.7 to 53.3, or as 59.1 to 67.45; from which if we subtract one portion of azote 17.54, there remain 49.91, so nearly 5 portions of oxygen, that we may assume 17.54 + 50, or 67.54, to be perfectly correct.

12. By dissolving 63 parts of carbonate of lime in muriatic acid, and evaporating to perfect dryness, we obtain 69.56 of muriate of lime; and deducting the weight of the lime, 35.46, we learn, by means of the difference 34.1, the equivalent of dry muriatic acid. Or, if we choose to consider the dry salt as a compound of calcium and chlorine, we must transfer the weight of 10 oxygen to the muriatic acid, making 44.1 of oxymuriatic acid combined with 25.46 calcium.

13. In oxalate of lead, according to Berzelius, 296.6 of litharge are united with 100 oxalic acid, which are in the proportion of 139.5 to 47 oxalic acid. A result almost exactly the same was obtained by Dr. Wollaston from the analysis of binoxalate of potash.

17, 18. The equivalent of soda is inferred from the analysis of common salt, in which the muriatic acid is to the soda as 100 to 114.78, or as 34.1 to 39.1. The equivalent of sodium is obtained by deducting 10 of oxygen, and is 29.1.

19, 20. In muriate of potash, the acid is to the alkali as 100 to

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* 2 Mém. d'Arcueil, 59.

173.47, or as 34.1 to 59.1, from which last number, if we deduct 10 the equivalent of oxygen, we obtain 49.1 for the equivalent of potassium.

21. The equivalent of magnesia is inferred from the composition of the sulphate, viz. 67 acid to 33 base; for as 67 to 33, so is 50 to 24.6.

22. The equivalent of lime is deduced from the carbonate of lime, in which the acid is to the earth as 43.7 to 56.3, or as 27.54 to 35.46; from which last number, deducting 10 oxygen, we have 25.46 for the equivalent of calcium.

24. In sulphate of strontites, the acid is to the earth as 42 to 58, or as 50 to 69.

25. In sulphate of barytes 34 acid are united with 66 earth, which is in the proportion of 50 to 97.

26. In black oxide of iron, the oxygen is to the metal as 22.5 to 77.5, or as 10 to 34.5, to which, adding 10 oxygen, we have 44.5 for the equivalent of the oxide of iron.

27. Black oxide of copper contains 20 oxygen to 100 metal, which gives 50 for the equivalent of oxide of copper, and 40 for that of the metal.

28. In oxide of zinc, the oxygen is to the metal as 24.41 to 100, or as 10 to 41, to which last number, adding 10 oxygen, we have 51 for the equivalent of oxide of zinc.

29. In red oxide of mercury, the oxygen is to the metal as 8 to 100, or as 10 to 125. But as other statements differ a little from this, 125.5 may be taken as a mean; and adding 10 oxygen, 135.5 will denote the red oxide.

30. In carbonate of lead, the acid is to the oxide as 16.5 to 83.5, or as 27.54 to 139.5, the equivalent of litharge; from which, deducting 10 oxygen, we have 129.5 for the equivalent of lead.

31. In muriate of silver, the acid is to the oxide of silver as 19.05 to 80.95, or as 34.1 to 145, the equivalent of the oxide, from which, if we take 10 oxygen, we have 135 the equivalent of silver. If we consider horn silver as a compound of 24.5 chlorine and 75.5 silver, the equivalent of silver will be 136; for 24.5 : 75.5 : : 44.1 : 136.

32. The subcarbonate of ammonia consists of acid and alkali, according to Guy Lussac, in the proportion of 56.02 to 43.98, or of 27.54 to 21.6, which, therefore, again proves to be the equivalent of ammonia. The two last numbers added together, give 49 for the equivalent of the subcarbonate.

33 In subcarbonate of soda, the acid is to the alkali as 41.24 to 58.76, or as 27.54 to 39.1; and the two last numbers, added together, express the equivalents of the subcarbonate.

35. The proportion of the elements of carbonate of lime is 43.7 acid to 56.3 base, or 27.54 to 35.46; and consequently carbonate of lime must be represented by those two numbers added together, viz 63.

36. In carbonate of barytes, the acid is to the earth as 100 to 352.57, or as 27.54 to 97, which two numbers, added together, 124.50, express the equivalent of carbonate of barytes.

37. The equivalent of carbonate of lead is obtained by adding together those of oxide of lead and of carbonic acid, (see 30.)

38, 39. For the determination of the equivalent of sulphuric acid see No. 7.

The remaining numbers, expressing the equivalents of compound bodies, are obtained by adding together the equivalents of their components. Thus the equivalent of muriate of potash 93.2 is obtained by adding together the equivalents of muriatic acid 34.1 and of potash 59.1.

No. 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 - -	Alkalies, Carbonate of magnesia, Muriate of barytes.
3. Alum - - - - - -	Alkalies, Muriate of barytes, Nitrate, muriate, carbonate of lime, Carbonate of magnesia.
4. Sulphate of magnesia	Alkalies, Muriate of barytes, Nitrate and muriate of lime.
5. Sulphate of iron - -	Alkalies, 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.

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[*] That is, salts which cannot exist together in solution, without mutual decomposition. This incompatibility, however, it is to be understood, exists only in solutions of a certain density.

No. V.—*Table of the Quantity of Oil of Vitriol* (sp. gr. 1.8485,) *and of Dry Sulphuric Acid, in* 100 *Parts, by Weight of diluted Acid, at different Densities. By* DR. URE.

(Journal of Science, &c. iv. 122.)

Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.
100	1.8485	81.54	66	1.5503	53.82	32	1.2334	26.09
99	1.8475	80.72	65	1.5390	53.00	31	1.2260	25.28
98	1.8460	79.90	64	1.5280	52.18	30	1.2184	24.46
97	1.8439	79.09	63	1.5170	51.37	29	1.2108	23.65
96	1.8410	78.28	62	1.5066	50.55	28	1.2032	22.83
95	1.8376	77.46	61	1.4960	49.74	27	1.1956	22.01
94	1.8336	76.65	60	1.4860	48.92	26	1.1876	21.20
93	1.8290	75.83	59	1.4760	48.11	25	1.1792	20.38
92	1.8233	75.02	58	1.4660	47.29	24	1.1706	19.57
91	1.8179	74.20	57	1.4560	46.48	23	1.1626	18.75
90	1.8115	73.39	56	1.4460	45.66	22	1.1549	17.94
89	1.8043	72.57	55	1.4360	44.85	21	1.1480	17.12
88	1.7962	71.75	54	1.4265	44.03	20	1.1410	16.31
87	1.7870	70.94	53	1.4170	43.22	19	1.1330	15.49
86	1.7774	70.12	52	1.4073	42.40	18	1.1246	14.68
85	1.7673	69.31	51	1.3977	41.58	17	1.1165	13.86
84	1.7570	68.49	50	1.3884	40.77	16	1.1090	13.05
83	1.7465	67.68	49	1.3788	39.95	15	1.1019	12.23
82	1.7360	66.86	48	1.3697	39.14	14	1.0953	11.41
81	1.7245	66.05	47	1.3612	38.32	13	1.0887	10.60
80	1.7120	65.23	46	1.3530	37.51	12	1.0809	9.78
79	1.6993	64.42	45	1.3440	36.69	11	1.0743	8.97
78	1.6870	63.60	44	1.3345	35.88	10	1.0682	8.15
77	1.6750	62.78	43	1.3255	35.06	9	1.0614	7.34
76	1.6630	61.97	42	1.3165	34.25	8	1.0544	6.52
75	1.6520	61.15	41	1.3080	33.43	7	1.0477	5.71
74	1.6415	60.34	40	1.2999	32.61	6	1.0405	4.89
73	1.6321	59.52	39	1.2913	31.80	5	1.0336	4.08
72	1.6204	58.71	38	1.2826	30.98	4	1.0268	3.26
71	1.6090	57.89	37	1.2740	30.17	3	1.0206	2.446
70	1.5975	57.08	36	1.2654	29.35	2	1.0140	1.63
69	1.5868	56.26	35	1.2572	28.54	1	1.0074	0.8154
68	1.5760	55.45	34	1.2490	27.72			
67	1.5648	54.63	33	1.2409	26.91			

No. VI.—*Table showing the Proportion of real or dry Nitric Acid, in* 100 *Parts of the liquid Acid, at successive Specific Gravities. By* DR. URE.

(Journal of Science, iv. 297.)

Specific gravity.	Acid in 100.	Specific gravity.	Acid in 100.	Specific gravity.	Acid in 100.
1.5000	79.700	1.3783	52.602	1.1833	25.504
1.4980	78.903	1.3732	51.805	1.1770	24.707
1.4960	78.106	1.3681	51,068	1.1709	23.910
1.4940	77.309	1.3630	50,211	1.1648	23.113
1.4910	76.512	1.3579	49,414	1.1587	22.316
1.4880	75.715	1.3529	48.617	1.1526	21.519
1.4850	74.918	1.3477	47.820	1.1465	20.722
1.4820	74.121	1.3427	47,023	1.1403	19.925
1.4790	73.324	1.3376	46,226	1.1345	19.128
1.4760	72.527	1.3323	45,429	1.1286	18.331
1.4730	71.730	1.3270	44,632	1.1227	17.534
1.4700	70.933	1.3216	43.835	1.1168	16.737
1.4670	70.136	1.3163	43,038	1.1109	15.940
1.4640	69.339	1.3110	42.241	1.1051	15.143
1.4600	68.542	1.3056	41.444	1.0993	14.346
1.4570	67.745	1.3001	40.647	1.0935	13.549
1.4530	66.948	1.2947	39.850	1.0878	12.752
1.4500	66.155	1.2887	39.053	1.0821	11.955
1.4460	65.354	1.2826	38.256	1.0764	11.158
1.4424	64.557	1.2765	37.459	1.0708	10.361
1.4385	63.760	1.2705	36.662	1.0651	9.564
1.4346	62.963	1.2644	35,865	1.0595	8.767
1.4306	62.166	1.2583	35.068	1.0540	7.970
1.4269	61.369	1.2523	34.271	1.0485	7.173
1.4228	60.572	1.2462	33.474	1.0430	6.376
1.4189	59.775	1.2402	32.677	1.0375	5.579
1.4147	58.978	1.2341	31.880	1.0320	4.782
1.4107	58.181	1.2277	31.083	1.0267	3.985
1.4065	57.384	1.2212	30.286	1.0212	3.188
1.4023	56.587	1.2148	29.489	1.0159	2.391
1.3978	55.790	1.2084	28.692	1.0106	1.594
1.3945	54.993	1.2019	27.895	1.0053	0.797
1.3882	54.196	1.1958	27.098		
1.3833	53.399	1.1895	26.301		

No. VII.—*Table of the Quantity of real or dry Muriatic Acid in 100 Parts of the liquid Acid, at successive Specific Gravities.* By Dr. Ure.

(Thomson's Annals of Philosophy, x. 371.)

Specific gravity.	Acid in 100.	Specific gravity.	Acid in 100.	Specific gravity.	Acid in 100.
1.1920	28.30	1.1272	18.68	1.0610	9.05
1.1900	28.02	1.1253	18.39	1.0590	8.77
1.1881	27.73	1.1233	18.11	1.0571	8.49
1.1863	27.45	1.1214	17.83	1.0552	8.21
1.1845	27.17	1.1194	17.55	1.0533	7.92
1.1827	26.88	1.1173	17.26	1.0514	7.64
1.1808	26.60	1.1155	16.98	1.0495	7.36
1.1790	26.32	1.1134	16.70	1.0477	7.07
1.1772	26.04	1.1115	16.41	1.0457	6.79
1.1753	25.75	1.1097	16.13	1.0438	6.51
1.1735	25.47	1.1077	15.85	1.0418	6.23
1.1715	25.19	1.1058	15.56	1.0399	5.94
1.1698	24.90	1.1037	15.28	1.0380	5.66
1.1679	24.62	1.1018	15.00	1.0361	5.38
1.1661	24.34	1.0999	14.72	1.0342	5.09
1.1642	24.05	1.0980	14.43	1.0324	4.81
1.1624	23.77	1.0960	14.15	1.0304	4.53
1.1605	23.49	1.0941	13.87	1.0285	4.24
1.1587	23.20	1.0922	13.58	1.0266	3.96
1.1568	22.92	1.0902	13.30	1.0247	3.68
1.1550	22.64	1.0883	13.02	1.0228	3.39
1.1531	22.36	1.0863	12.73	1.0209	3.11
1.1510	22.07	1.0844	12.45	1.0190	2.83
1.1491	21.79	1.0823	12.17	1.0171	2.55
1.1471	21.51	1.0805	11.88	1.0152	2.26
1.1452	21.22	1.0785	11.60	1.0133	1.98
1.1431	20.94	1.0765	11.32	1.0114	1.70
1.1410	20.66	1.0746	11.04	1.0095	1.41
1.1391	20.37	1.0727	10.75	1.0076	1.13
1.1371	20.09	1.0707	10.47	1.0056	0.85
1.1351	19.81	1.0688	10.19	1.0037	0.56
1.1332	19.53	1.0669	9.90	1.0019	0.28
1.1312	19.24	1.0649	9.62	1.0000	0.00
1.1293	18.96	1.0629	9.34		

No. VIII.—*Colour of the Precepitates thrown down from Metallic Solutions by various Re-agents.*

Metals.*	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphureted Hydrogen.	Hydro-Sulphurets
Gold	Yellowish-white	Solution turned green. Precipitate brown of reduced gold	Yellow	Yellow
Platinum	No precip.; but an orange coloured one by pruss. of mercury	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			Noprecip
Iridium	No precipitate. Colour discharged	No precipitate. Colour of solutions discharged		
Osmium		Purple, changing to deep vivid blue		

* Chevenix. † Wollaston.

Colour of Precipitates from Metallic Solutions, &c.—Continued.

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphureted Hydrogen.	Hydro-Sulphurets
Copper	Bright reddish brown	Brownish	Black	Black
Iron — 1. Green salts	White, changing to blue.	No precipitate.	Not precipitated	Black
Iron — 2. Red salts	Deep blue	Black.		
Nickel	Green	Grayish white	Not precipitated	Black
Tin	White	No precip	Brown	Black
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 precipitate	Not precipitated	White
Chrome	Green	Brown		Green

Colour of Precipitates from Metallic Solutions, &c.—Continued.

Metals.	Prussiated Alkalies.	Tincture of Galls.	Water impregnated with Sulphureted Hydrogen.	Hydro-Sulphurets.
Molybdena	Brown	Deep brown	Brown	
Uranium	Brownish red	Chocolate		Brownish yellow
Tungsten				
Titanium	Grassgreen with a tinge of brown	Reddish brown	Not precipitated	Grass green
Columbium	Olive	Orange		Chocolate
Tantalium				
Cerium		Yellowish		Brown becoming deepgreen

No. IX.—*Table of Simple Affinity.*[*]

OXYGEN.	OXYGEN.†	NITROGEN.	Arsenic
			Molybdena
Carbon	Titanium	Oxygen	
Charcoal	Manganese	Sulphur?	
Manganese	Zinc	Phosphorus	
Zinc	Iron	Hydrogen	POTASH, SODA, AND AMMONIA.
Iron	Tin		
Tin	Uranium		
Antimony	Molybdena		*Acids.*
Hydrogen	Tungsten	HYDROGEN.	Sulphuric
Phosphorus	Cobalt		Nitric
Sulphur	Antimony	Oxygen	Muriatic
Arsenic	Nickel	Sulphur	Phosphoric
Nitrogen	Arsenic	Carbon	Fluoric
Nickel	Chrome	Phosphorus	Oxalic
Cobalt	Bismuth	Nitrogen	Tartaric
Copper	Lead		Arsenic
Bismuth	Copper		Succinic
Caloric	Tellurium	SULPHUR.	Citric
Mercury	Platinum	PHOSPHORUS?	Lactic
Silver	Mercury		Benzoic
Arsenous Acid	Silver	Potash	Sulphurous
Nitric oxide	Gold	Soda	Acetic
Gold		Iron	Mucic
Platinum		Copper	Boracic
Carbonic oxide		Tin	Nitrous
Muriatic acid	CARBON.	Lead	Carbonic
White oxide of manganese		Silver	Prussic
	Oxygen	Bismuth	Oil
White oxide of lead	Iron	Antimony	Water
	Hydrogen	Mercury	Sulphur

---

[*] 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.

BARYTES.

- *Acids.*
  - Sulphuric
  - Oxalic
  - Succinic
  - Fluoric
  - Phosphoric
  - Mucic
  - Nitric
  - Muriatic
  - Suberic
  - Citric
  - Tartaric
  - Arsenic
  - Lactic
  - Benzoic
  - Acetic
  - Boracic
  - Sulphurous
  - Nitrous
  - Carbonic
  - Prussic
- Sulphur
- Phosphorus
- Water
- Fixed oils

STRONTITES.

- *Acids.*
  - Sulphuric
  - Phosphoric
  - Oxalic
  - Tartaric
  - Fluoric
  - Nitric
- *Acids.*
  - Muriatic
  - Succinic
  - Acetic
  - Arsenic
  - Boracic
  - Carbonic
- Water

LIME.

- *Acids.*
  - Oxalic
  - Sulphuric
  - Tartaric
  - Succinic
  - Phosphoric
  - Mucic
  - Nitric
  - Muriatic
  - Suberic
  - Fluoric
  - Arsenic
  - Lactic
  - Citric
  - Malic
  - Benzoic
  - Acetic
  - Boracic
  - Sulphurous
  - Nitrous
  - Carbonic
  - Prussic
- Sulphur
- Phosphorus
- Water
- Fixed oil

MAGNESIA.

- *Acids.*
  - Oxalic
  - Phosphoric
  - Sulphuric
  - Fluoric
  - Arsenic
  - Mucic
  - Succinic
  - Nitric
  - Muriatic
  - Tartaric
  - Citric
  - Malic?
  - Lactic
  - Benzoic
  - Acetic
  - Boracic
  - Sulphurous
  - Nitrous
  - Carbonic
  - Prussic
- Sulphur

ALUMINE.

- *Acids.*
  - Sulphuric
  - Nitric
  - Muriatic
  - Oxalic
  - Arsenic
  - Fluoric
  - Tartaric
  - Succinic
  - Mucic
- *Acids.*
  - Citric
  - Phosphoric
  - Lactic
  - Benzoic
  - Acetic
  - Boracic
  - Sulphurous
  - Nitrous
  - Carbonic
  - Prussic

SILEX.

- Fluoric acid
- Potash

OX. OF PLATINUM. GOLD.*

- Gallic acid
- Muriatic
- Nitric
- Sulphuric
- Arsenic
- Fluoric
- Tartaric
- Phosphoric
- Oxalic
- Citric
- Acetic
- Succinic
- Prussic
- Carbonic
- Ammonia

---

[*] Omitting the oxalic, citric, succinic, and carbonic, and adding sulphureted hydrogen after ammonia.

Table of Simple Affinity,—Continued.

OXIDE OF SILVER.

Gallic acid
Muriatic
Oxalic
Sulphuric
Mucic
Phosphoric
Sulphurous
Nitric
Arsenic
Fluoric
Tartaric
Citric
Lactic
Succinic
Acetic
Prussic
Carbonic
Ammonia

OXIDE OF MERCURY.

Gallic acid
Muriatic
Oxalic
Succinic
Arsenic
Phosphoric
Sulphuric
Mucic
Tartaric
Citric
Malic
Sulphurous
Nitric
Fluoric
Acetic
Benzoic
Boracic
Prussic
Carbonic

OXIDE OF LEAD.

Gallic
Sulphuric
Mucic
Oxalic
Arsenic
Tartaric
Phosphoric
Muriatic
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 alkalies
Ammonia
Fixed oils

OXIDE OF ARSENIC.

Gallic
Muriatic
Oxalic
Sulphuric
Nitric
Tartaric
Phosphoric
Fluoric
Succinic
Citric
Acetic
Prussic
Fixed alkalies
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
Arsenic
Phosphoric
Nitric
Succinic
Fluoric
Mucic

---

* Bergman places the tartaric before the muriatic.

Table of Simple Affinity,—Continued.

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 alkalies
Ammonia

OXIDE OF ANTIMONY.

Gallic
Muriatic

Benzoic
Oxalic
Sulphuric
Nitric
Tartaric
Mucic
Phosphoric
Citric
Succinic
Fluoric
Arsenic
Lactic
Acetic
Boracic
Prussic
Fixed alkalies
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
Zircon
Metallic oxides

PHOSPHORIC ACID.
CARBONIC[‡]

Barytes
Strontites
Lime
Potash
Soda
Ammonia
Magnesia
Glucine
Alumine
Zircon
Metallic oxides
Silex

PHOSPHOROUS ACID.

Lime
Barytes
Strontites
Potash
Soda
Ammonia
Glucine
Alumine
Zircon
Metallic oxides

NITRIC ACID.
MURIATIC—[§].

Barytes
Potash
Soda
Strontites
Lime
Magnesia
Ammonia
Glucine
Alumine
Zircon
Metallic oxides

FLUORIC ACID.
BORACIC——[‖]
ARSENIC——[¶]
TUNGSTIC——

Lime

---

[*] With the omission of all after ammonia.

[†] Ammonia should come before magnesia; and strontites, glucine, and zircon should be omitted.

[‡] Magnesia should stand above ammonia, and alumine and silica should be omitted.

[§] Ammonia should stand above magnesia.

[‖] Silex should be omitted, and instead of it, water and alcohol be inserted.

[¶] Except silex.

Table of Simple Affinity,—Continued.

Barytes
Strontites
Magnesia
Potash
Soda
Ammonia
Glucine
Alumine
Zircon
Silex

ACETIC ACID.
LACTIC ——
SUBERIC*.

Barytes
Potash
Soda
Strontites
Lime
Ammonia
Magnesia
Metallic oxides
Glucine
Alumine

Zircon

OXALIC ACID.
TARTARIC —
CITRIC —†

Lime
Barytes
Strontites
Magnesia
Potash
Soda
Ammonia
Alumine
Metallic oxides
Water
Alcohol

BENZOIC ACID.

White oxide of arsenic
Potash

Soda
Ammonia
Barytes
Lime
Magnesia
Alumine

CAMPHORIC ACID.

Lime
Potash
Soda
Barytes
Ammonia
Alumine
Magnesia

FIXED OIL.

Lime
Barytes
Potash
Soda

Magnesia
Oxide of mercury
Other metallic oxides
Alumine

ALCOHOL.

Water
Ether
Volatile oil
Alkaline sulphurets

SULPHURETED HYDROGEN.

Barytes
Potash
Soda
Lime
Ammonia
Magnesia
Zircon

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* With the omission of strontites, metallic oxides, glucine, and zircon.

† Zircon after alumine.

ADDENDA.

I have thought it proper to annex a short account of some discoveries, which have been published in the different philosophical journals, while this work was passing through the press.

Cadmium. A new metal, to which this name has been given, was discovered by M. Stromeyer, in the autumn of 1817. Hitherto, it has been found only in the oxide of zinc, prepared for medicinal use, from an ore of zinc that came from Silesia. The process, by which it was separated, has not been published; but the following are described as its most remarkable properties[*].

Cadmium resembles tin in its colour, lustre, softness, ductility, and in the sound which it emits when doubled. Its specific gravity is 8.6350. It melts, and volatillizes, at a temperature a few degrees below that required by tin. It is not tarnished by the air; but, when heated, is converted into an orange coloured oxide, which is not volatile, and is easily reducible.

Oxide of cadmium does not tinge borax when fused with it. It readily dissolves in acids, and forms with them soluble salts, from which it is precipitated white by alkalies, and yellow, like arsenic, by sulphureted hydrogen. From these solutions, zinc throws it down in a metallic state.

Sirium. Of this supposed new metal, it is unnecessary to say more, than that it has been proved to be merely a compound of sulphur, iron, nickel, and arsenic[†].

Malic and Sorbic Acids. By a careful investigation of the *malic* acid, M. Braconnot has been led to the conclusion, that it is essentially the same with the *sorbic*, and that, when divested of all impurities, it exhibits the same properties, and forms exactly the same compounds; a conclusion supported also, by the experiments of Houton Labillardière[‡]. By a process somewhat complicated, the former succeeded in detaching the pure acid of the juice of houseleek (*sempervivum tectorum*, *L*:) from a substance with which it is associated, holding apparently a middle place between gum and sugar, and so modifying the properties of the acid, as to have led to erroneous views of its nature. In the juices of other vegetables, it is probable that the impurities mixed with it will be found of a different kind.

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[*] Ann. de Chim. et Phys. viii. 100; or Journal of Science, vi. 111.

[†] Thomson's Annals, xii. 312. Faraday, in Journal of Science, vi. 112.

[‡] Ann. de Chim. et Phys. viii. 149, 214.

The identity of the two acids having thus been rendered unquestionable, it appears reasonable to distinguish their common ingredient, by the name originally applied to it by its discoverer Scheele, and to discontinue the appellation of *sorbic* acid ; since the latter is nothing more than the *malic* deprived of impurities.

The RHEUMIC ACID, (vol.ii. p. 230,) has been lately shown by M. Lassaigne to be merely the oxalic, disfigured by certain impurities[*].

PURPURIC ACID. This acid has been obtained, also, (but apparently of less purity than by Dr. Prout,) by Brugnatelli, Junior[†]. He has proposed to call it *erythric acid* (from ἐρυθραίνειν, to redden,) and its compounds *erythrates*. Those, who are interested on the subject, will find Brugnatelli's Memoir, at full length, in the Philosophical Magazine, for July, 1818.

NEW ALKALI OF VEGETABLE ORIGIN. MM. Pelletier and Caventou, in analyzing *nux vomica*, and the *bean of St. Ignatius*, have extracted a peculiar substance, possessing alkaline properties, to which the powerful action of those poisons on the animal economy appears to be owing[‡].

The new substance is white, crystalline, and insufferably bitter. It occurs in quadrangular plates, or in prisms of four sides, terminated by a four-sided pyramid. It is slightly soluble in water, but readily so in alcohol. It restores the blue colour of reddened litmus paper, and, with the acids, forms neutral salts that are soluble in water, and more or less easily crystallizable. Hence in its chemical properties, it seems to present a considerable resemblance to *morphium*, but when taken into the stomach, it produces, in a more intense degree, the effects of the tincture of *nux vomica*. From the circumstance of M. Vauquelin's having observed an analogous substance in the *Daphne Alpina*, its discoverers have proposed for it the name of *Vauqueline*.

TRIPLE PRUSSIATE OF POTASH—PRUSSIC ACID—AND THE NEW GAS OBTAINED BY DR. THOMSON.

By distilling triple prussiate of potash with rather more than twice its weight of strong sulphuric acid, Dr. Thomson has obtained a gas, which, after being freed from sulphurous acid, evolved along with it, was found to possess new properties. Its smell is peculiar, and bears no resemblance to that of any other gas ; it is permanent over water ; has the specific gravity of 0.993, air being 1000. When slowly burned from an orifice it exhibits a deep blue flame. By rapid combustion in a Volta's eudiometer, three volumes consume two of oxygen, and give three volumes of carbonic acid. It appears to be constituted of

$$\left.\begin{array}{l}\text{3 volumes of carbonic oxide}\\ \text{1 volume of hydrogen gas}\end{array}\right\}\text{ condensed into 3 volumes.}$$

Dr. Thomson has proposed to call it *hydrogureted carbonic oxide*.

The *triple prussiate of potash* has also been submitted to a fresh

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[*] Ann. de Chim. et Phys. viii. 402.

[†] Ibid. 201 ; or Phil. Mag. lii. 30.

[‡] Ann. de Chim. et Phys. viii. 323 ; or Journal of Science, vi. 149.

examination both by Dr. Thomson, and by Mr. Porrett. The former describes it as crystallizing, when perfect, in plates with bevelled edges, usually about half an inch thick, and two or three inches in diameter; the two faces of the bevelled edges being inclined to each other at an angle of about 135°. Its colour is a fine topaz yellow. When held between the eye and the light, it is transparent, and appears green. Its specific gravity is 1.833. It may be split into flexible plates, parallel to the bases of its pyramids. One hundred parts of water at 54° Fahrenheit dissolve 27.8 of the salt; at 100°, 65.8 parts; at 150°, 87.6 parts; and at 200°, 90.6. In alcohol it is not soluble at all.

According to Dr. Thomson, the salifying principle of this salt appears, from experiment, to be constituted of half an atom of metallic iron with one atom of prussic (hydro-cyanic) acid; and the triple salt itself consists of

Acid	Iron	15.0	45.90
	Matter gasified by heat	30.9	
Potash			41.64
Water			13.
			100.54

Exhibiting a small excess of 0.54 in 100 of the salt[*].

Since, however, the proportion of iron, as deduced from the equivalent of the acid ingredient of the triple prussiate (66.11, oxygen being 10,) ought to be one atom to one atom of hydro-cyanic acid, there appeared, with respect to the acid of the triple prussiate, to be a disagreement between the atomic theory and the results of analysis. This disagreement Mr. Porrett has endeavoured to rectify by a fresh series of experiments[†]. He detached the potash, from 50 grains of the triple salt, by 70 grains of crystallized tartaric acid; and obtained a quantity of bi-tartrate, denoting 17.9 grains of potash; consequently 100 grains must contain 35.8. The water being 13 grains, the acid in 100 grains must be 51.2. This acid Mr. Porrett supposes to be a compound, not of prussic acid and iron, according to Dr. Thomson, but of the elements of two atoms of prussic acid, an atom of azote[†], an atom of iron, or, in other words, it consists of

4 atoms carbon	30.16
1 atom azote	17.54
1 atom iron	34.50
2 atoms hydrogen	2.64

Its atom, therefore, weighs . . . 84.84

When it unites with potash, one atom of acid takes one atom of base (59.10,) and two atoms of water (22.64,) which gives the composition of the triple prussiate as follows:

---

[*] Annals of Philosophy, xii. 110.

[†] Ibid. xii. 214.

Acid - - -	50.93
Potash - - -	35.48
Water - - -	13.59
	100.

Mr. Porrett analyzed the acid of this salt, by distilling the triple prussiate, as Dr. Thompson had done, with per-oxide of copper, only using a larger proportion of the oxide: and he found that the resulting carbonic acid and azote agreed, as nearly as could possibly be expected, with the proportions that ought to be produced according to the theoretical view. This acid, therefore, does not appear to present any exception to the general principles of the atomic theory. As to its nomenclature, Mr. Porrett is disposed to abide by that which he formerly proposed *ferrureted chyazic acid;*) because, according to his view the acid does not consist of prussic acid and iron; but of a part of the elements of prussic acid in union with that metal.

OXYMURIATE (CHLORIDE) OF LIME. This compound has been examined by Welter,* who determines it to consist of hydrate of lime united with chlorine, in the following proportions, oxygen being considered as 10:

1 atom of chlorine - - - - - - -	44.1
2 atoms hydrate of lime† 46.78 × 2 =	93.56
	137.66

Seven parts of hydrate of lime, fully saturated with chlorine, gave, in his experiments, 10.22 of oxymuriate of lime, which destroyed the colour of as much solution of indigo, as the chlorine itself, calculated to be present in the salt, would have destroyed. He considers it, therefore, as a true compound of chlorine, and not of chloric acid with hydrate of lime; and if this view be correct, its proper appellation will be *chloride of hydrated lime.* The proportions in 100 parts may be calculated from the data of Welter as follows:

Chlorine - - -	32.04	or	1 atom	= 44.10
Water - - - -	22.64		2 atoms	= 22.64
Lime - - - -	70.92		2 atoms	= 70.92
	100.			137.66

When dissolved in water, Welter agrees with Mr. Dalton, that one atom of the hydrate of lime is separated, and that the solution contains a compound of one atom of hydrate of lime and one atom

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* Ann. de Chim. et Phys. vii. 383.

† The atoms of this hydrate containing

Lime - - -	35.46
Water - -	11.32
	46.78

of chlorine. They differ, however, so materially in the proportions of the salt (see vol. i. p. 461,) that its analysis is still deserving of further investigation.

New Combinations of Oxygen with the known Acids.

By treating the per-oxide of barium (vol. i. p. 255,) with acids, Thenard has succeeded in forming new combinations of those acids with oxygen.* The process consists simply in dissolving per-oxide of barium (prepared by heating pure barytes in oxygen gas, and moistening the product with water sufficient to change it into a white powder,) in any acid intended to be oxygenated; and then adding a due proportion of sulphuric acid. This carries down the protoxide of barium, leaving the acid united with the oxygen which the per-oxide has abandoned.

Oxy-nitric acid is liquid, colourless, and resembles nitric acid in its chemical agencies. It is decomposed by being heated to the boiling temperature, and abandons its oxygen, of which, by proper management, it may be made to yield eleven times its volume. It unites with alkaline and earthy bases; but the resulting salts are so easily decomposed, that they can scarcely be obtained in crystals. It acts on all those metals that are soluble in common nitric acid, but has no power of dissolving gold.

In oxy nitric acid, the elements were determined by Thenard to be present, in the proportion of 100 volumes of nitrogen to 300 oxygen; and hence its atomic constitution is 1 atom of nitrogen to 6 atoms of oxygen. It stands, therefore, at the head of the series given in vol. i. p. 381, 383, as the most highly oxygenated compound of nitrogen.

The phosphoric, arsenic, and acetic acids, were oxygenated by a similar treatment, but not the sulphuric; and contrary to what might have been expected, the muriatic acid was brought into combination with oxygen, which, it might have been supposed, would have acted only on the hydrogen of that acid. Thenard was not able, however, to obtain oxymuriatic acid in a very concentrated state. Heat decomposed it into oxygen and muriatic acid, and its salts were also easily destructible. It was very acid, colourless, almost free from smell, and strongly reddened litmus. It dissolved zinc without effervescence, but had no action on gold. With oxide of silver, it exhibited a brisk effervescence, owing to the escape of oxygen gas. By means of the oxy-muriatic acid, its discoverer succeeded in oxygenating the fluoric acid, which was found to retain its oxygen at the temperature of ebullition.

These facts are extremely curious and important, and open a wide field for new and interesting discoveries. It is remarkable, that the oxy-muriatic acid, really entitled to that name, should differ essentially in its properties from the body formerly so designated;

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* Ann. de Chim. et Phys. viii. 306.

and that it should want the leading characters of the latter, viz. its power of destroying vegetable colours, and of acting on gold.

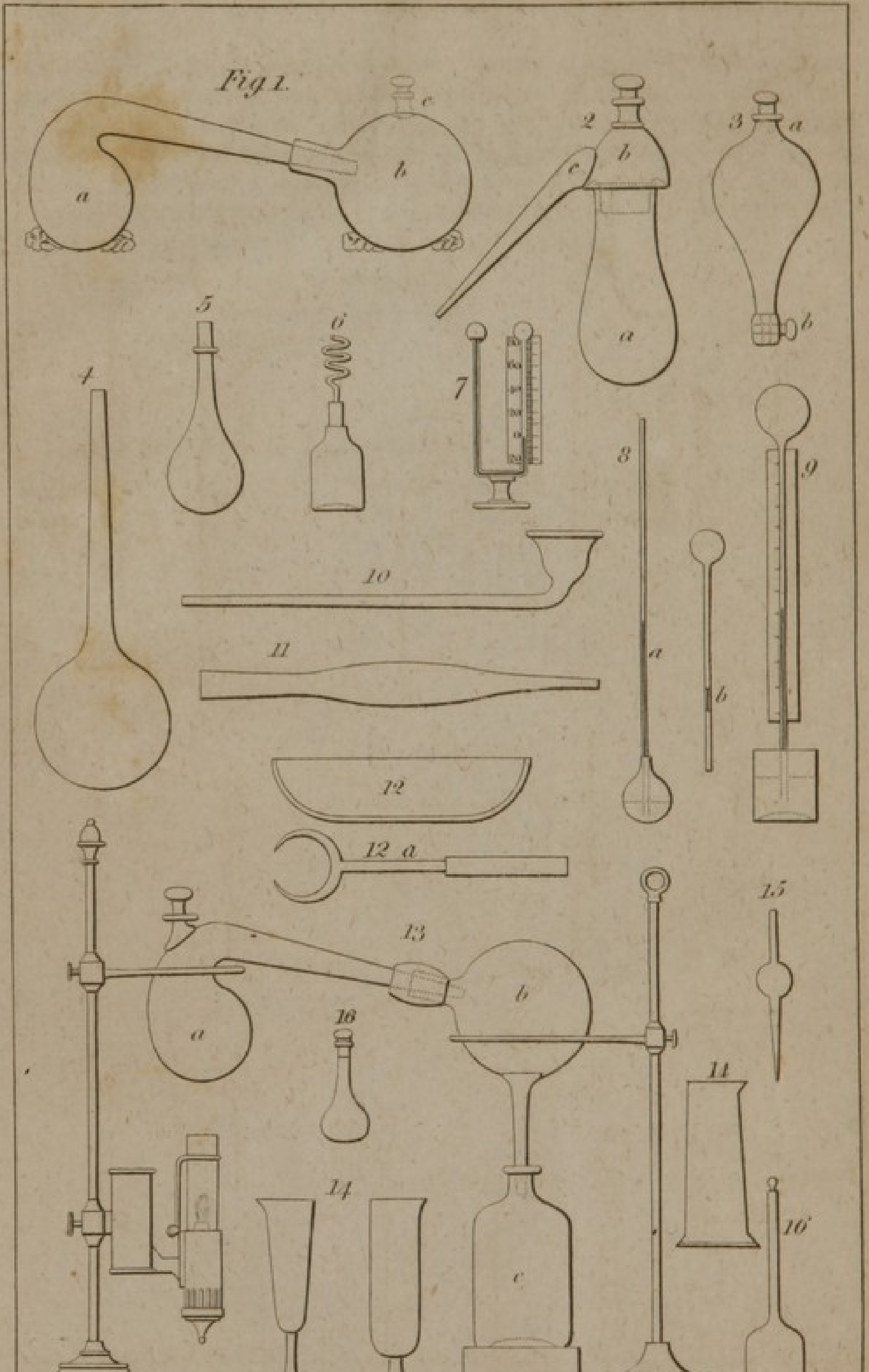
Analysis of Alum. This salt has lately been carefully analyzed by Mr. Richard Phillips, with the result that the potash exists in it, not in the state of a simple sulphate, but of *bi-sulphate*. The true composition of alum appears from these experiments (not yet published) to be, taking 10 for the atom of oxygen,

2 atoms sulphate of alumine	164
1 atom bi-sulphate of potash	159.1
22 atoms of water	249.6
	572.7

Hence 100 parts of alum consist of

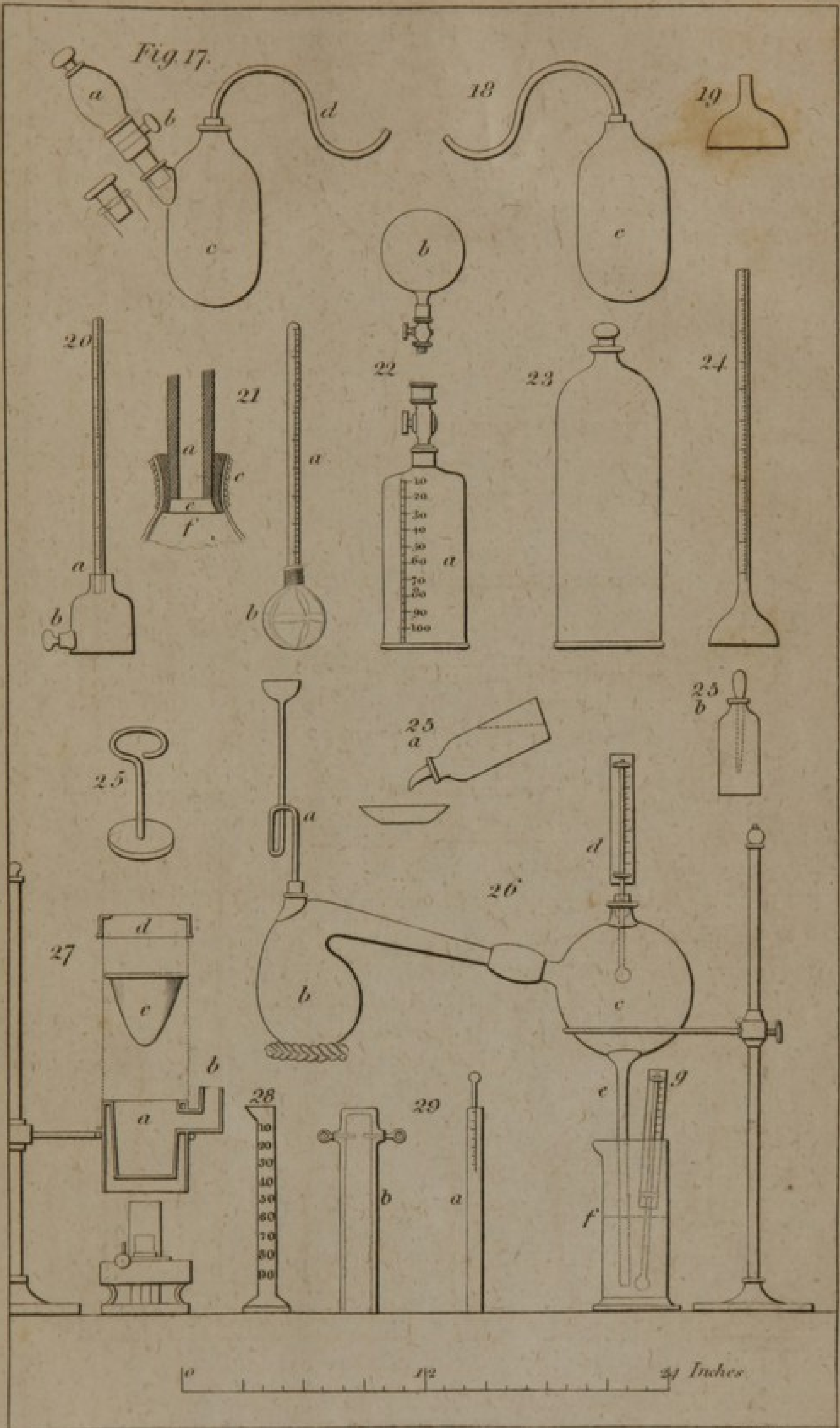
Alumine	11.18	or	Sulph. of alumine	28.65
Sulph. acid	34.94		Sulph. of potash	19.065
Potash	10.33		Sulph. acid	8.735
Water	43.55		Water	43.55
	100.00			100.00

Pl. I.



C. Tiebout S.

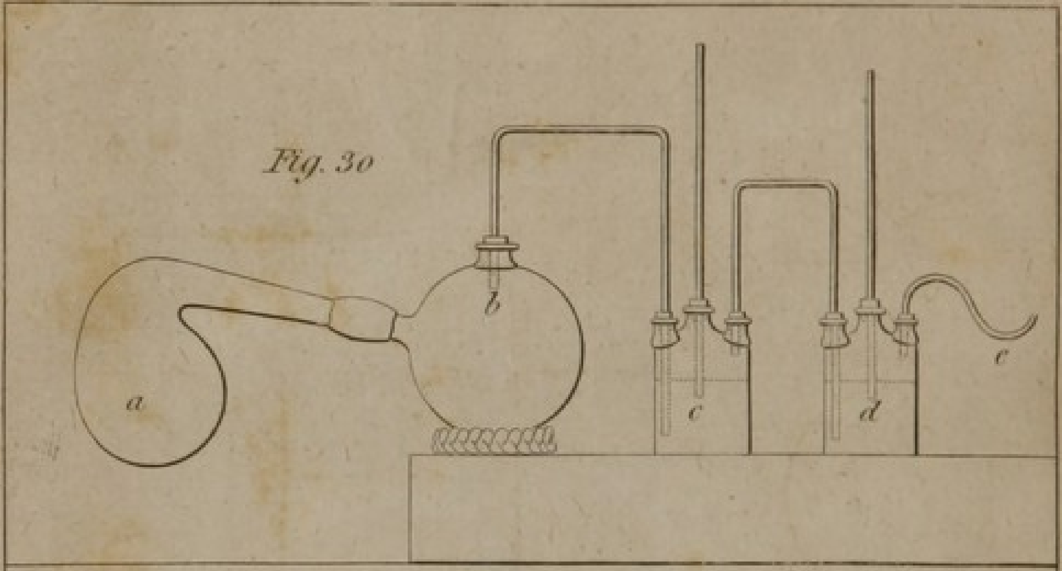
Pl. II.



C. Tiebout S.

Pl. III.

Fig. 30



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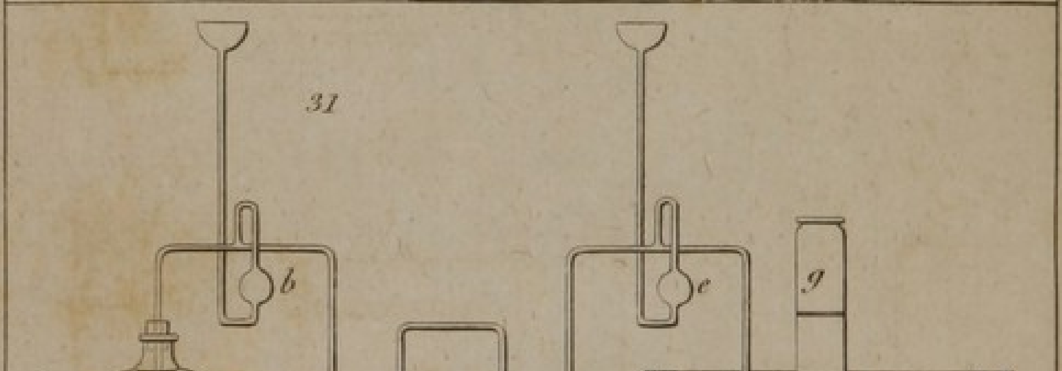

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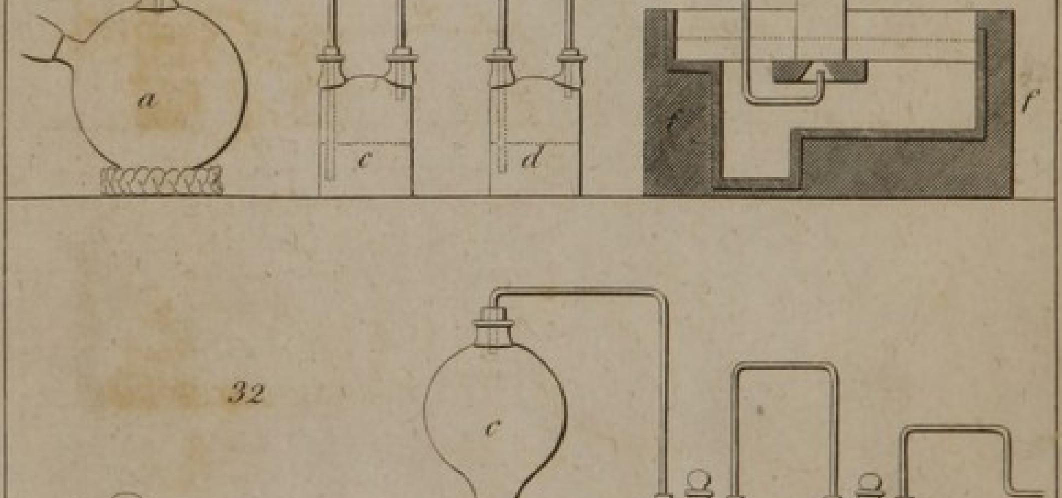

C. Tiebout S.

Fig. 33

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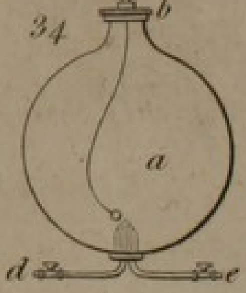

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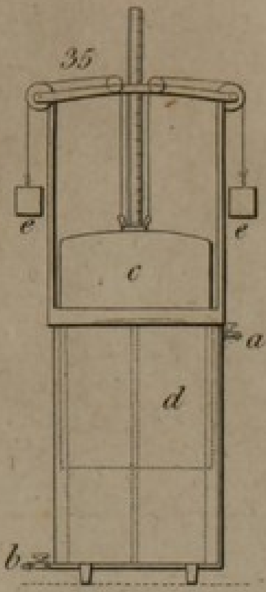

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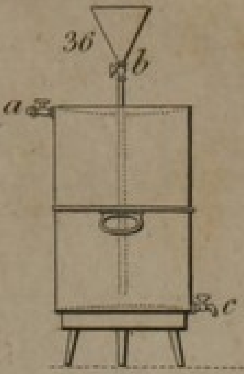

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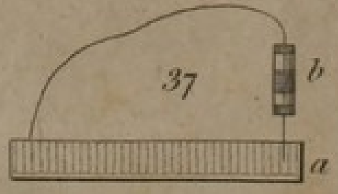

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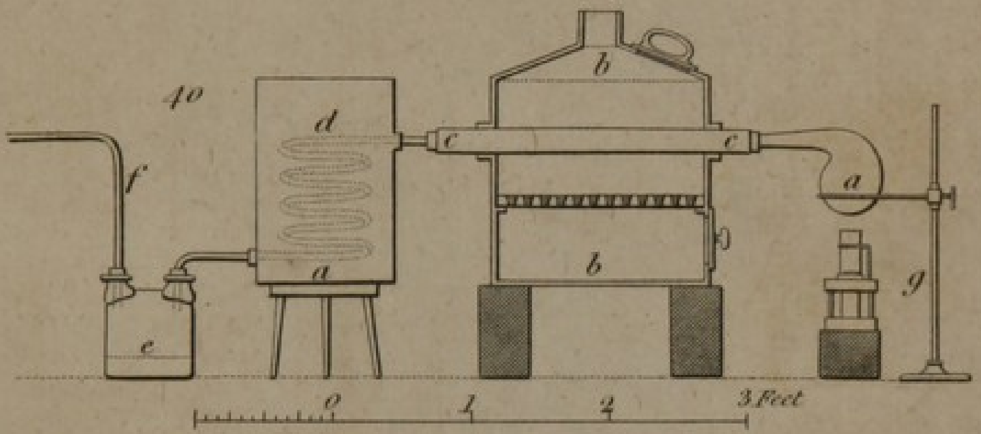

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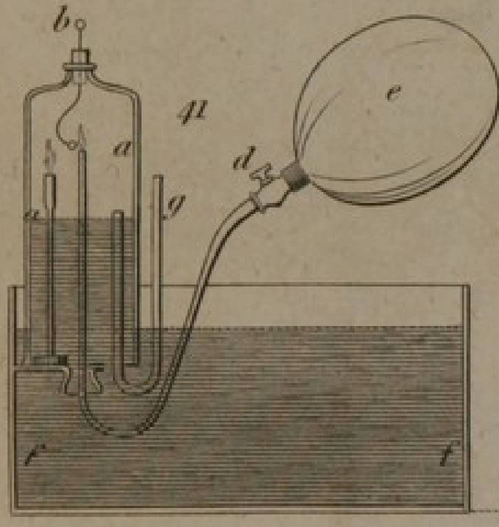

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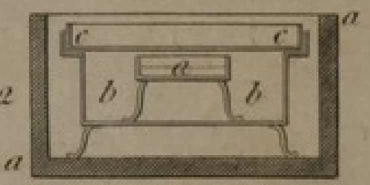

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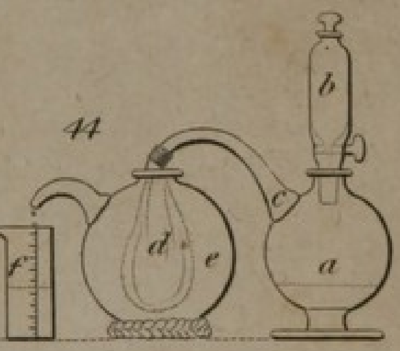

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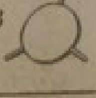
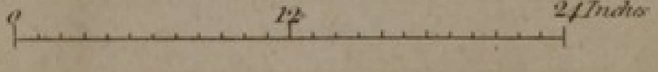
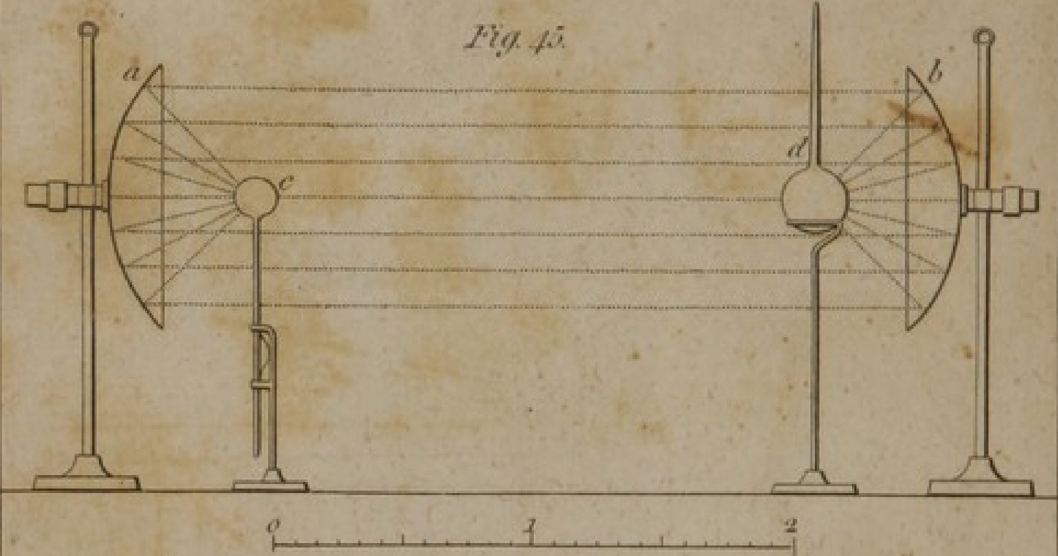
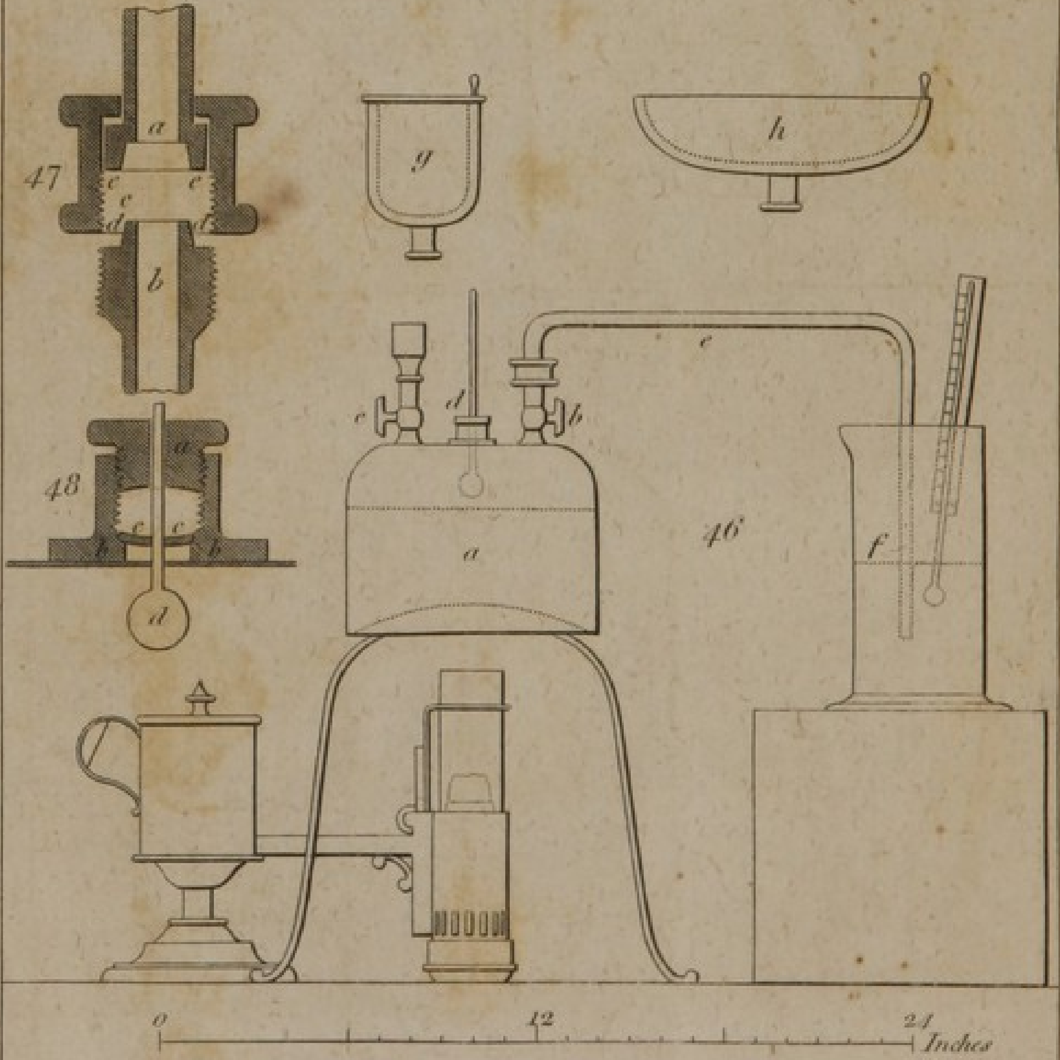




C. Tiebout Sc.

Fig. 45.





C. Tiebout Sc.

Pl. VI.

Fig. 49.

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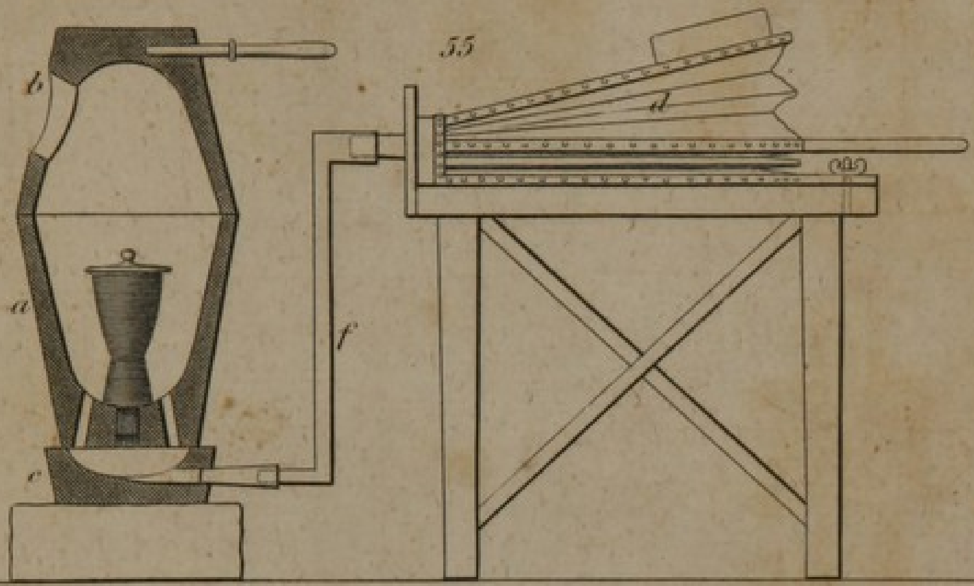

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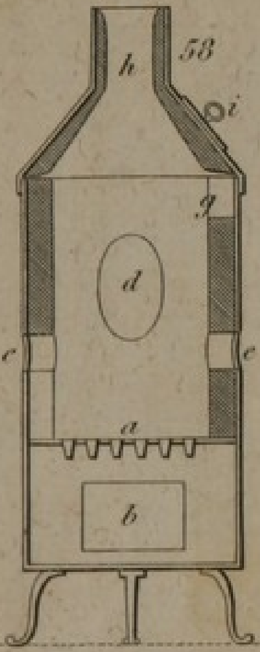

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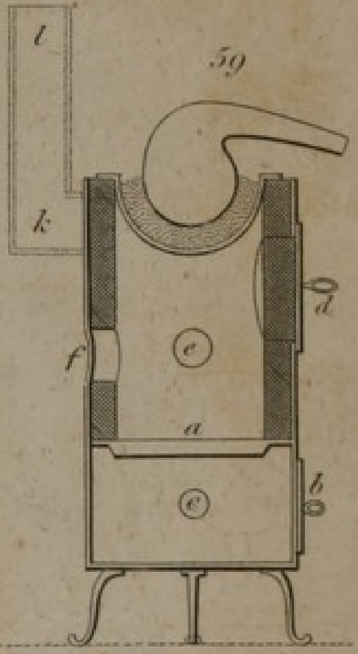
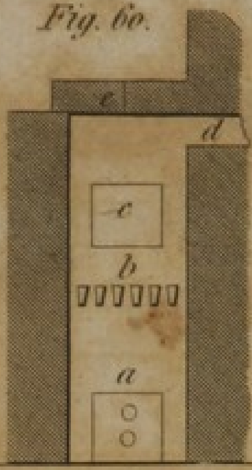


C. Tiebout Sc.

Fig. 60.



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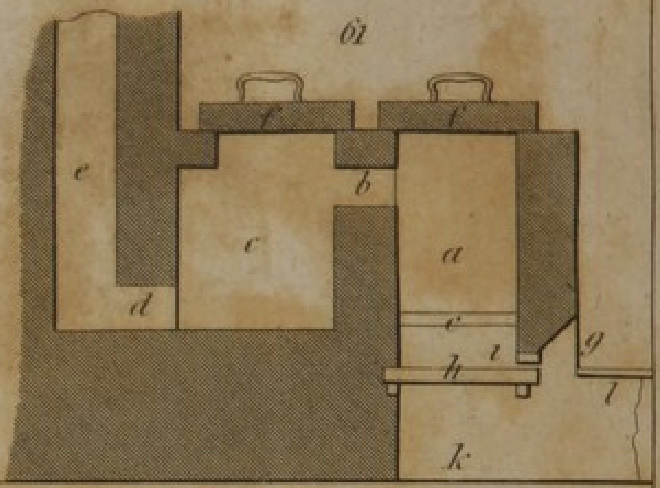

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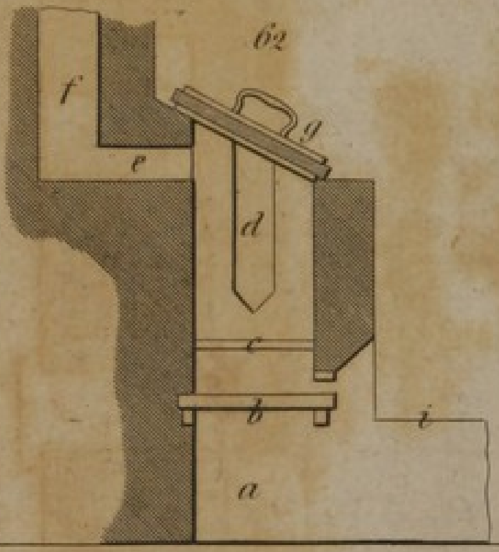

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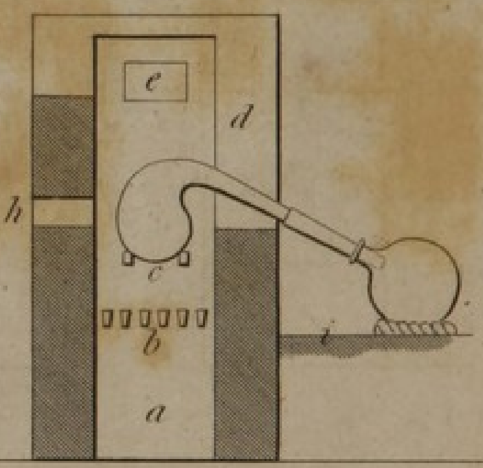

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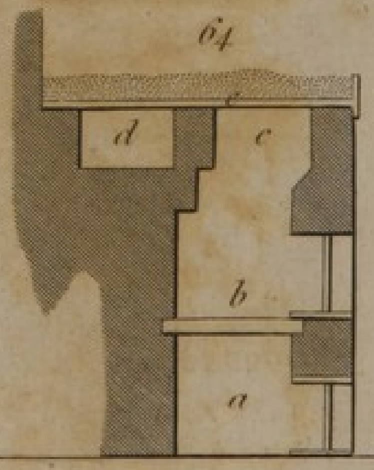

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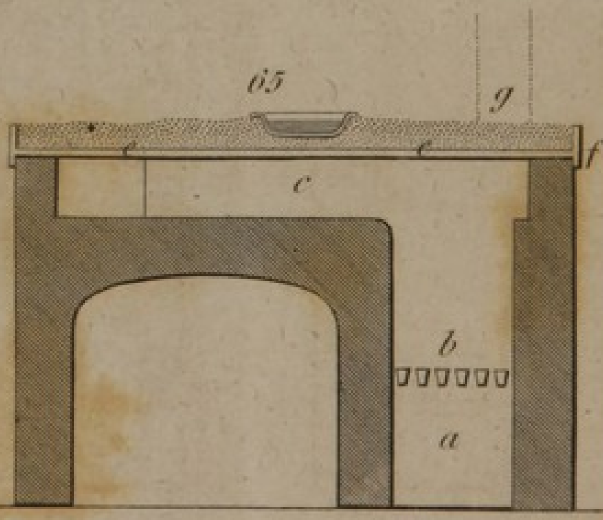
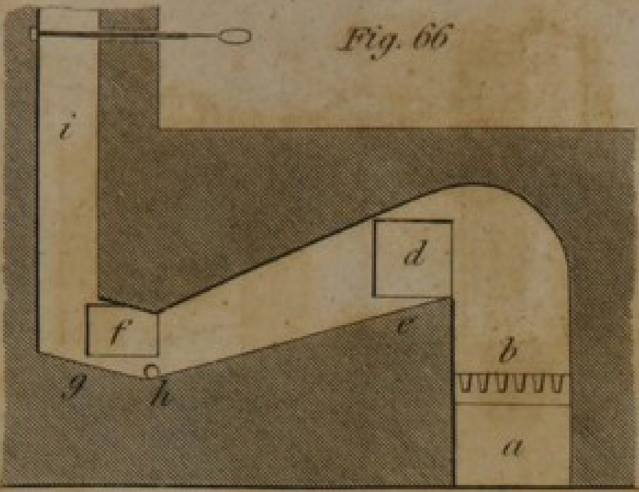


C. Tiebout S.

Fig. 66



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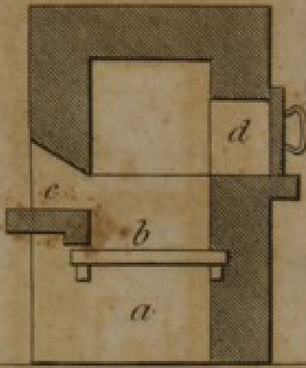

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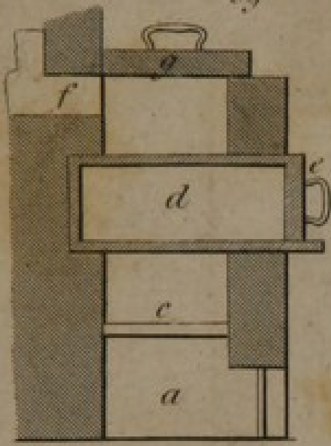

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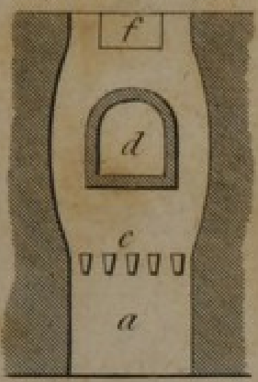

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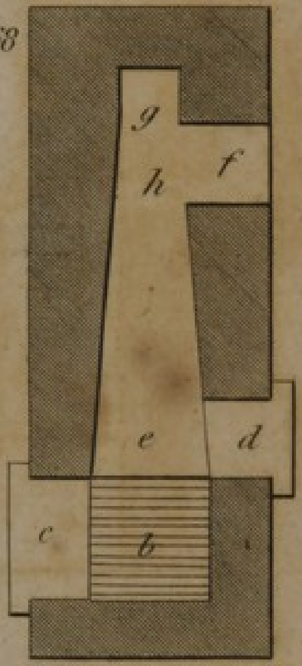

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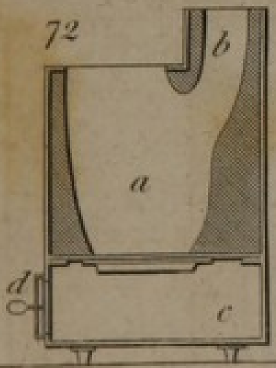

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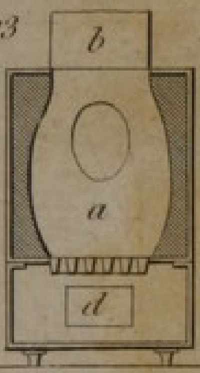

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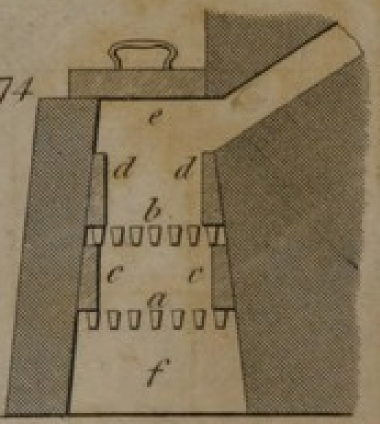
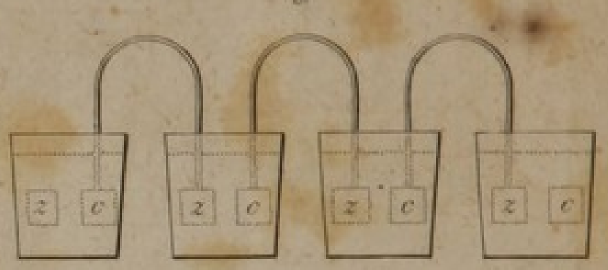


C. Tiebout. S.

76.

Fig. 75.



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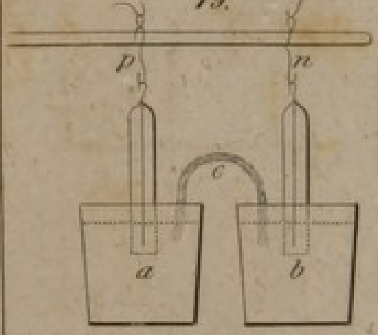

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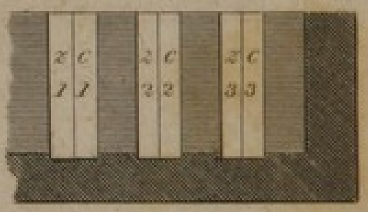

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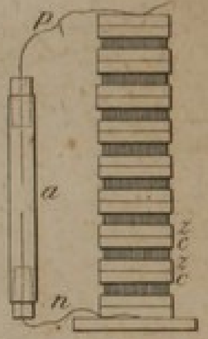

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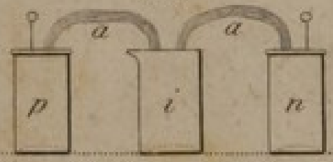

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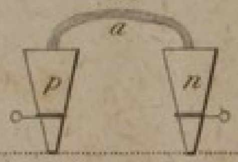

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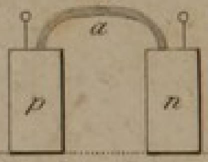

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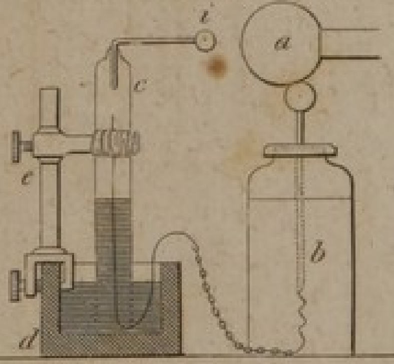

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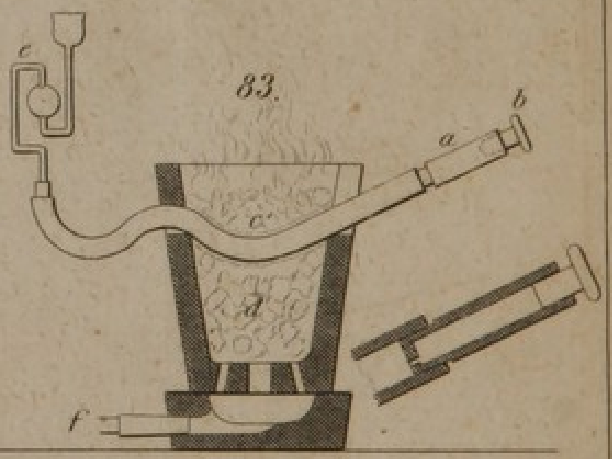

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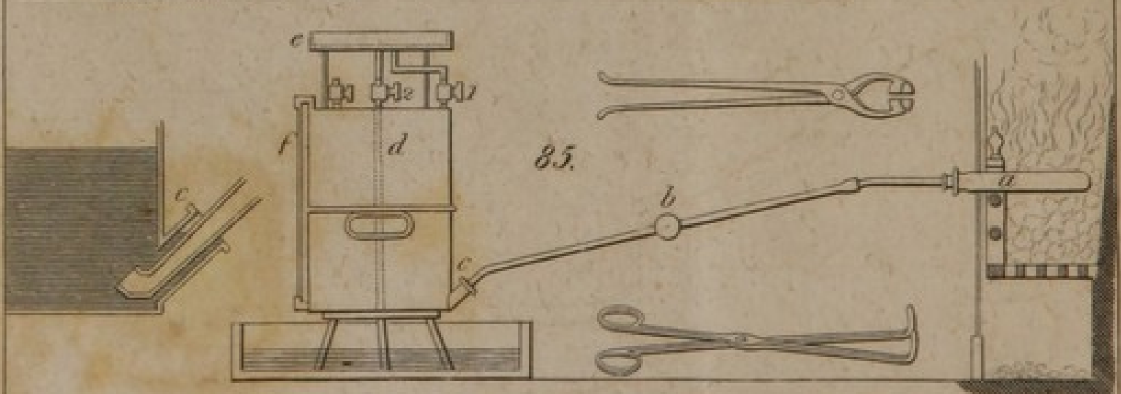

C. Tiebout Sc^t

Fig. 1.

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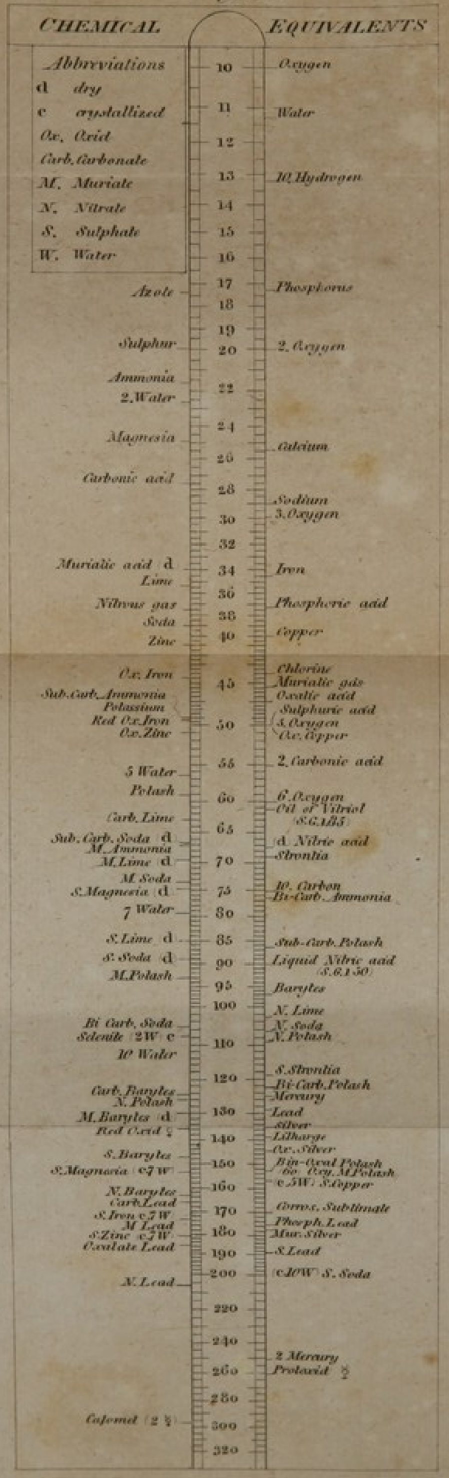
C. Tiebout Sc.

Fig. 1.



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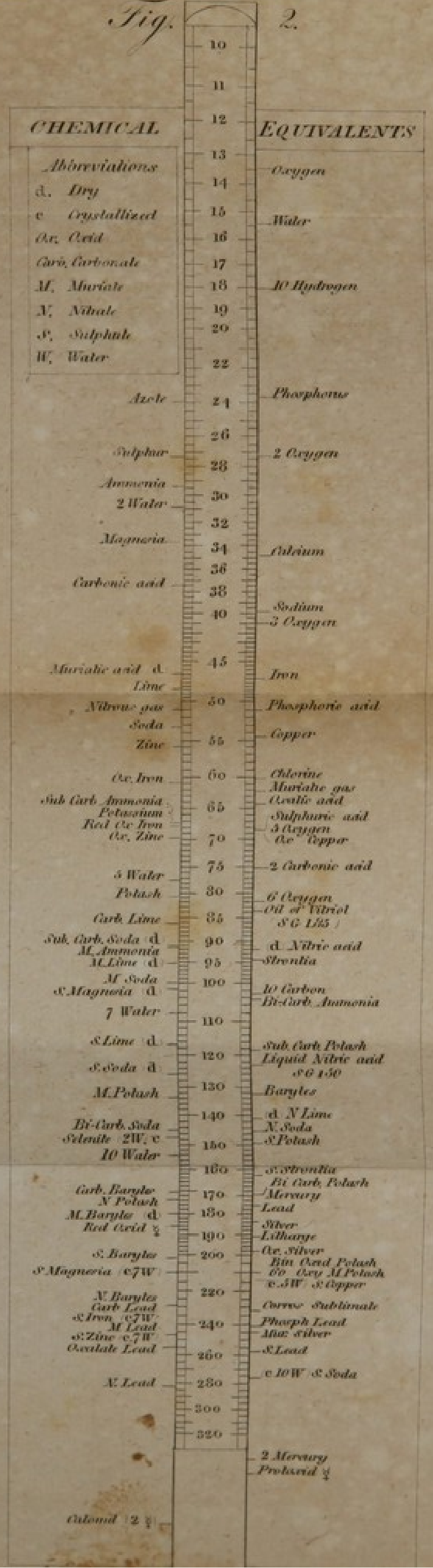
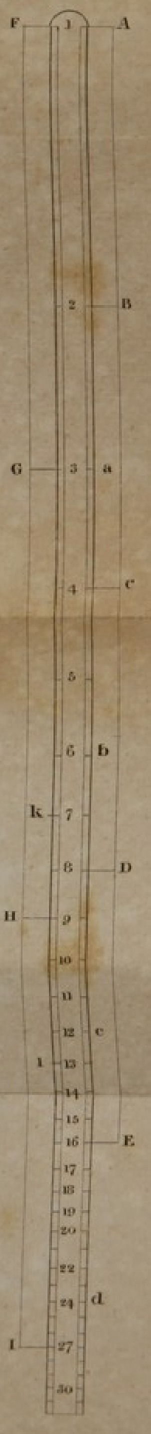


Fig. 3.



CALORIMOTOR.

Fig. 1.

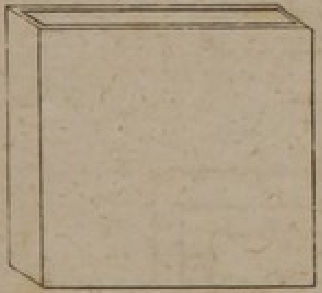


Fig.1.

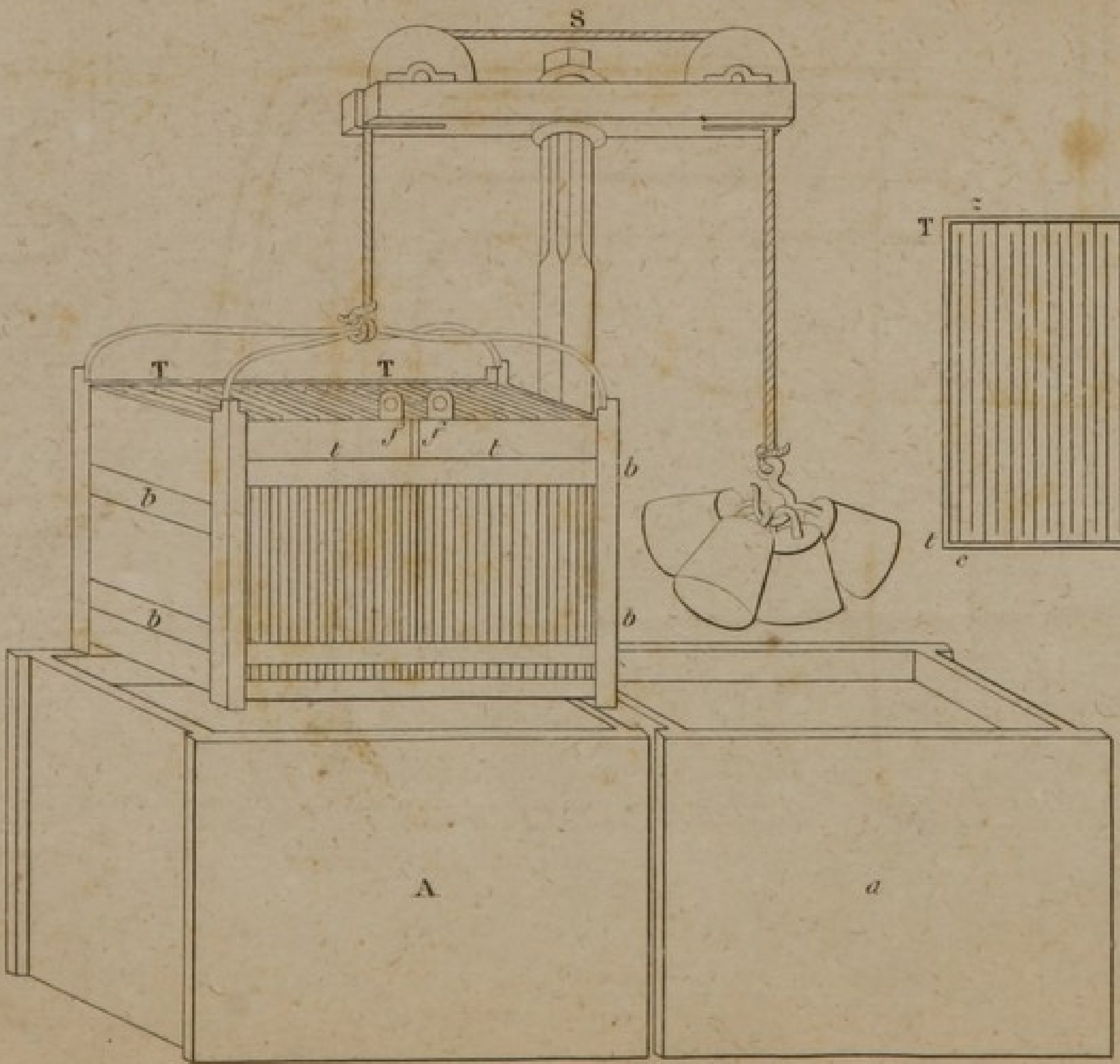
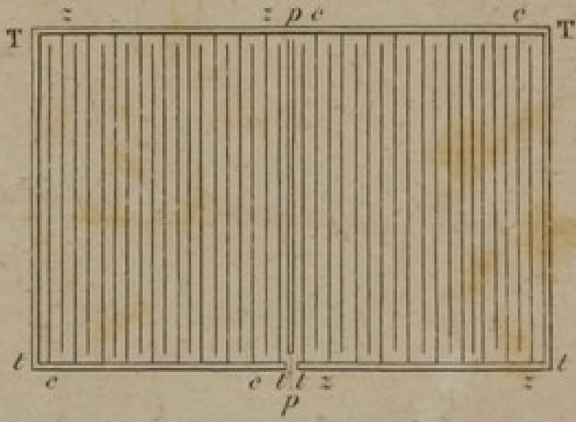


Fig. 2.



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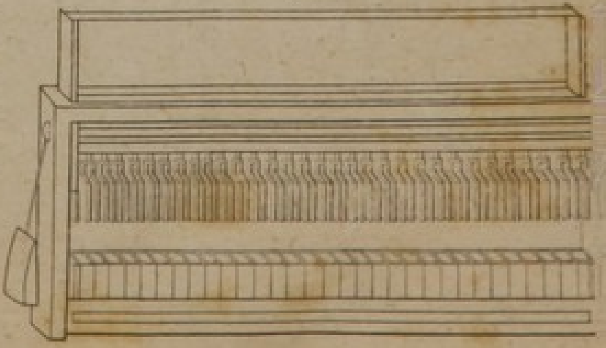

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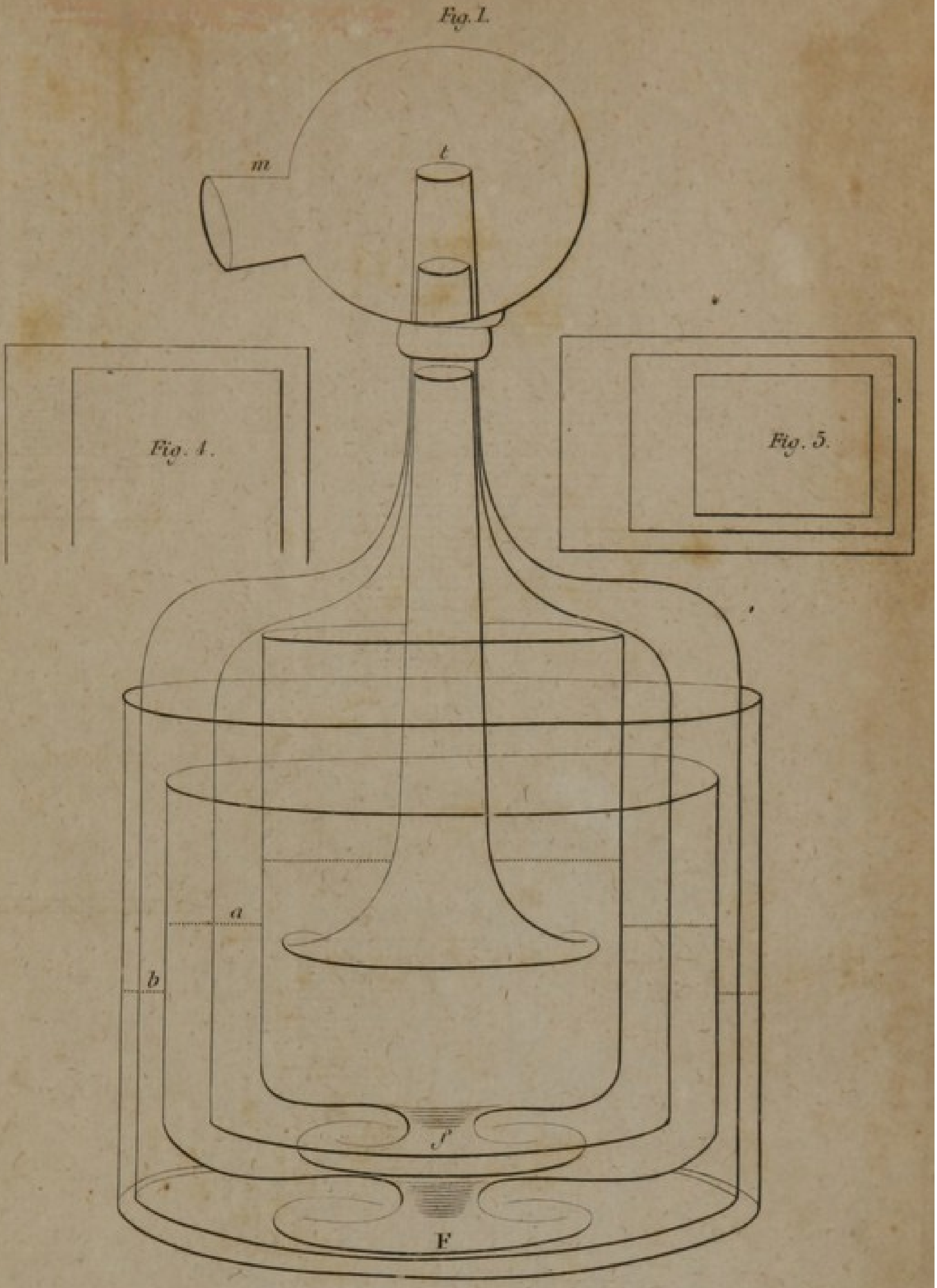

Fig. 3.

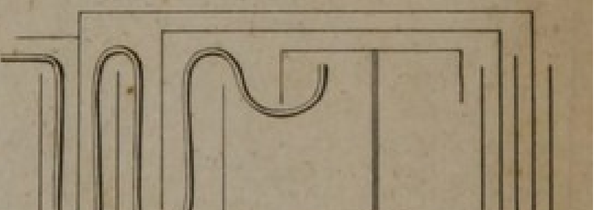

Fig. 2.

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