

## **Elements of chemistry, in two volumes / by John Murray.**

### **Contributors**

Murray, John.

### **Publication/Creation**

Edinburgh : Printed for Adam Black and Longman, Rees, Orme, Brown and Green ..., 1828.

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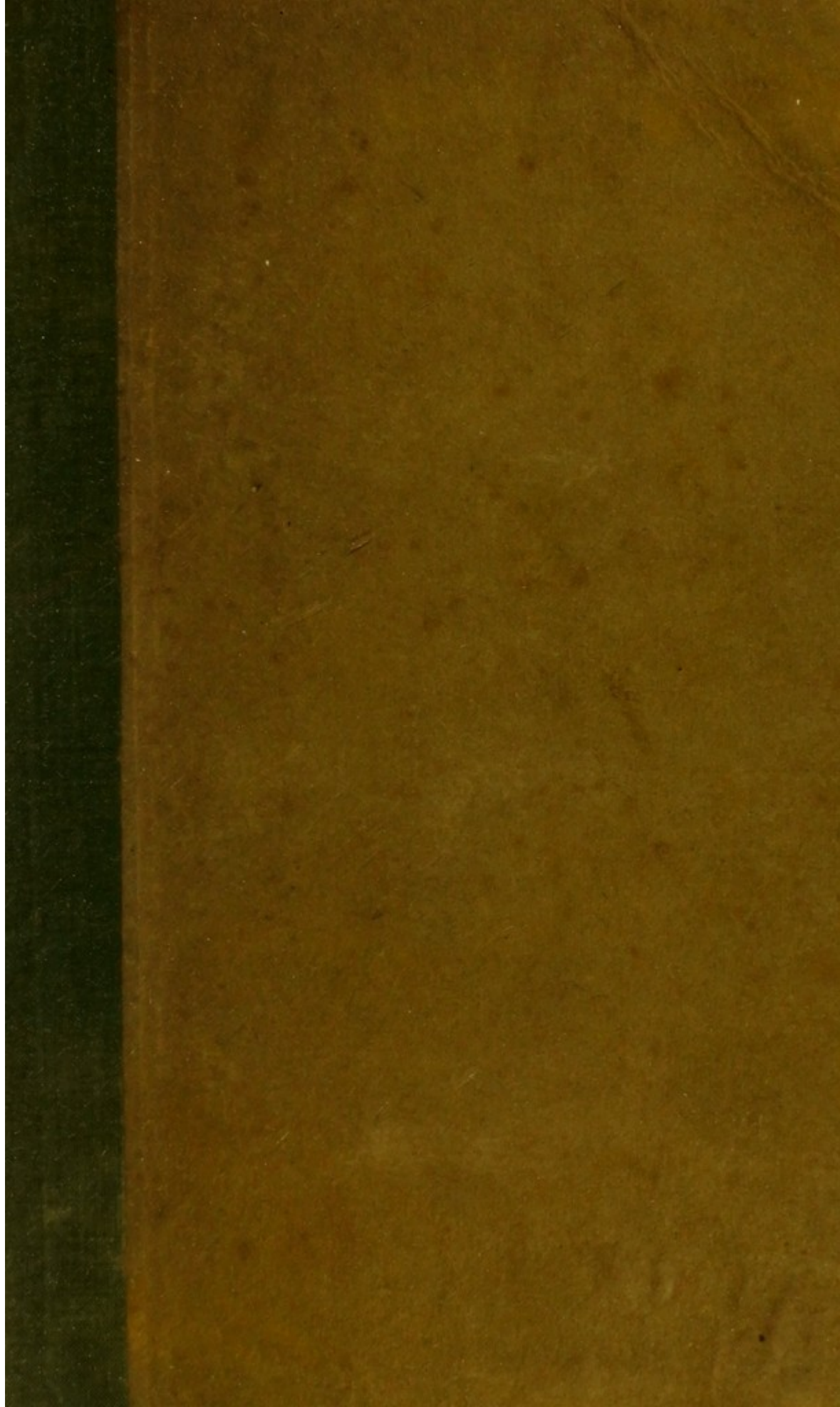
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ELEMENTS  
OF  
CHEMISTRY.

IN TWO VOLUMES.

BY  
JOHN MURRAY, M. D.

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS, OF THE ROYAL SOCIETY  
OF EDINBURGH, THE GEOLOGICAL SOCIETY OF LONDON, &c. ; LECTU-  
RER ON CHEMISTRY, AND ON MATERIA MEDICA AND PHARMACY.

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*Sixth Edition,*  
*INCLUDING ALL THE RECENT DISCOVERIES,*  
AND ADAPTED TO THE PRESENT STATE OF THE SCIENCE:

BY  
JOHN MURRAY,  
FELLOW OF THE ROYAL COLLEGE OF SURGEONS, AND LECTURER ON  
CHEMISTRY, EDINBURGH.

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VOLUME SECOND.

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EDINBURGH:  
PRINTED FOR ADAM BLACK, NORTH BRIDGE STREET;  
AND LONGMAN, REES, ORME, BROWN AND GREEN,  
LONDON.

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1828.

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FELLOW OF THE ROYAL SOCIETY OF EDINBURGH, OF THE ROYAL SOCIETY OF LONDON, &c.; ASSISTANT OF PHYSICS, THE MEDICAL SOCIETY OF LONDON, &c.; ASSISTANT OF CHEMISTRY, AND OF MATERIA MEDICA AND PHARMACY.

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PRINTED FOR ADAM BLACK, NORTH BRIDGE STREET; AND FOR GEORGE LEITCH, CORN LANE, LONDON.

EDINBURGH

LONDON

PRINTED BY JAMES WALKER.

1828.



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## BOOK IV.

### OF ALKALIS AND THEIR BASES.

AN order of substances possessed of certain common properties has been distinguished by the name of Alkalis. They are soluble in water ; their taste is acrid ; and when applied to animal matter, they erode or dissolve it ; they change the blue and purple colours of vegetables to a green ; the yellow they change to a brown : they combine with oils and fats forming soaps : Lastly, they unite with the different acids, forming compounds in which, when the due proportion is observed, the characteristic qualities of both are lost or neutralized, so that the presence of the acid or of the alkali cannot, from any remaining property of either of them, be recognised. Three alkalis have been long known ; they are named Ammonia, Soda, and Potash, (or what, for similarity of termination, is by some considered preferable, Potassa.) The first of these, Ammonia, existing when uncombined in the aërial form, and being, even when combined with water, easily volatilized, has been named Volatile Alkali ; the other two, though they are volatilized at a red heat, yet still having comparative fixity, are denominated Fixed Alkalis. Some newly discovered bodies have been lately arranged in the same class.



The most characteristic property of the alkalis is that displayed in their relations to the acids, namely, their combining with them, and forming compounds in which the peculiar acid powers are neutralized. But the same property is possessed by another order of chemical agents, the Earths; and several of these approach closely, in other respects, to the alkalis, being soluble in water, acrid and caustic, combining with oils, and changing the vegetable colours to a green. In the leading property common to both, the analogy is even still farther extended; for the compounds of the metals with oxygen, the Metallic Oxides, as they are named, are also capable of combining with the acids, and of neutralizing the acid powers. Thus, the whole of these bodies are connected into one series; and though the Alkalis, Earths, and Metallic Oxides may each be distinguished, by some peculiar characters, as a subordinate order, still they are all strictly allied in their most important chemical relations; and the transition is nearly uninterrupted, from the substance placed at the commencement of the one division, through those belonging to the others.

The analogy between these three orders has been rendered perfect by the discovery, that the alkalis and earths are compounds of bases of a metallic nature with oxygen; that under this point of view, therefore, they are actually metallic oxides. The earths resembling the more common metallic oxides in many of their properties, had frequently been supposed to be metallic; but the same supposition had scarcely been extended to the alkalis, partly as their properties are more remote from those of metallic oxides, and partly from the composition of ammonia having been discovered, by which it was proved to have no connection with metallic matter, but to consist merely of the two gases, hydrogen and nitrogen. Sir H. Davy



succeeded in effecting the decomposition of the alkalis by galvanic action, and obtained from them oxygen and bases having metallic properties. He submitted the earths to the same powerful instrument of analysis; and though their decomposition was less perfect, it was sufficiently so to demonstrate that they also consist of metallic bases in an oxidated state. And thus, the whole series of substances capable of neutralizing acids, and so strictly connected in other general properties, were, with the exception of ammonia, proved to be composed of metals combined with an oxygen; and an uninterrupted gradation was established from the alkalis to the earths, and from them to the metallic oxides.

Though the alkalis, earths, and metallic oxides have been connected by these discoveries, there remain sufficient reasons to arrange them as distinct orders. The bases of the alkalis and the earths, admitting them to be metallic, possess marked distinctions from the common metals, both in physical and chemical properties; and except in the leading character of combining with the acids, the alkalis are very different in their qualities from the metallic oxides, and are much more active in their chemical relations. The earths approach nearer to the metallic oxides, and form the link connecting them with the alkalis. In this series, then, of alkalis, earths, and metallic oxides, the history of these substances will be given\*.

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\* As this arrangement is somewhat different from that commonly followed, in which the earths and greater number of the alkalis are included among the metallic oxides, it may be proper to make some remarks on the advantages which Dr Murray's method possesses. The principle of his arrangement, it has been already stated, is to class bodies into certain general orders, as Atmospheric Air, Water, Acids, Alkalis, Earths, &c. the characters of which



Several of the earths, particularly barytes and strontites, approach so nearly to the alkalis in their properties, that

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are obvious and easily defined, and of which the student, even in beginning the study of the science, may have some general idea; and to place in connection with the history of each substance, the account of its constituents and their combinations, bodies which are less familiarly known to us. Thus, under the history of atmospheric air, its elements, oxygen and nitrogen, were described: under that of water, hydrogen was noticed: under sulphuric acid, sulphur and its various compounds were described. In like manner, in connection with the chemical history of potash, that of potassium will be given: sodium will be noticed in connection with soda, &c. The opposite mode has been followed in most chemical works. The simple bases, of which no one, unless he is previously acquainted with the science, has any knowledge, are described first, and afterwards their compounds, such as they occur in nature, or are obtained in the processes of art,—a method which certainly appears to me to reverse the proper manner of teaching a science, by beginning with those substances which are more recondite, and more difficult to be obtained and examined, and proceeding afterwards to those which are more familiar to us. In this latter method it has been mentioned the classes of Alkalis and Earths are expunged, and these important agents are placed amongst metallic oxides,—an arrangement liable to other objections of considerable weight. Thus, the class of metals, which was before so extensive, that it was difficult to recollect and to discriminate the individual bodies which it included, is, in this way, still farther enlarged. Instead of 29 metals, which are classed together in Dr Murray's arrangement, in the common method not less than 40, and these varying from each other in every degree, are enumerated in one series. A consequence of this is, that the characters of a class so extensive, and composed of bodies of such different properties, must be vague and deficient; and accordingly, the class of metals, as commonly defined, has not a single distinctive character. In Dr Murray's arrangement, all the substances placed together as metals agree in a property, than which none can be more obvious or more certain,—



it has been proposed to transfer them to this class. They are still, however, on the whole, more strictly connected with the other earths : and if the entire series is to be subdivided into orders, it could not be done with more propriety, than into the three which have been stated. The alkalis may be regarded as associated and distinguished from the others by their much greater solubility in water, and affinity for it ; by their solubility in alcohol ; by their greater fusibility and volatility, and in general by their greater activity as chemical agents.

Some newly discovered substances, it has been stated, have been added to this class. Of these, one, Lithina, is found to exist in certain minerals, and is hence properly associated with the others, potash and soda, which also occur in a number of minerals. There are others, as Morphia or Morphine, Cinchonine, &c. which are exclu-

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great specific gravity. But in the other mode of placing the alkalis and earths, as metallic oxides, this prominent distinction is lost, potassium and sodium being lighter than water, and the other metalloids little heavier ; and the anomaly is thus presented, of classing these with platina and gold, which are more than twenty times heavier. Another inconvenience attending the common arrangement regards one of the alkalis, ammonia, which in alkaline qualities is not inferior to either of the others, and is indeed closely related to them in all its agencies, yet not having a metallic base, is not associated with them, but in most chemical works occupies a singular situation, being placed beside olefiant gas, phosphuretted and sulphuretted hydrogen, and other compounds of hydrogen, to none of which certainly does it bear the smallest resemblance. In Dr Murray's arrangement alone is it placed in a situation corresponding to its characters. For these, and other reasons which might be stated, Dr Murray's arrangement has always appeared to me preferable to every other, and I have accordingly strictly followed it in the text. ED.



sively products of the vegetable system; and as the vegetable acids are placed under the class of vegetable substances, these bodies are, on the same principle, to be referred to that class.

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## CHAP. I.

### OF AMMONIA.

THIS alkali, obtained by indirect processes, was known to the older chemists only in its combination with water, forming the liquid which, from its volatility compared with the other alkalis, was denominated Volatile Alkali. Dr Priestley first shewed, that a gas can be procured from this liquor by a moderate heat, and that the pure alkali is a permanently elastic fluid: it is therefore called Ammonia or Ammoniacal gas, and its solution in water is called Liquid Ammonia.

In the progress of pneumatic chemistry, several facts were observed, proving the composition of ammonia. Priestley found, that on taking the electric spark in the gas, or on transmitting it through an ignited earthen tube, the volume is much enlarged, and its properties are changed; it is no longer absorbed by water, and is highly inflammable. By heating certain metallic oxides in the ammoniacal gas, he further found, that they were reduced to the metallic state; a little water was produced, and the residual gas was nitrogen. Berthollet, guided by the experiments of Priestley and Scheele, was led by them to institute others, in which ammonia was decomposed: and, from the whole, he first inferred that it is a compound of



hydrogen and nitrogen gas. In its decomposition by heat, he shewed that it is resolved into these two gases alone; and when it is decomposed by metallic oxides, he explained the formation of water and evolution of nitrogen, by inferring that the hydrogen of the ammonia unites with the oxygen of the oxide, while the nitrogen is liberated.

The composition of ammonia is not easily established by synthesis, the elasticity of the two gases being an obstacle to the exertion of the affinity of their gravitating matter, so that when mixed together they cannot be combined, even by the agency of the electric spark. It had been observed, however, that in some cases of chemical action, ammonia is evidently formed, or is evolved, though it does not pre-exist in the materials. This production of it was known to take place in the action of nitric acid on tin; and the theory of its production, as well as the principle on which it depends, were ascertained by Dr Austin. Tin being a metal having a great avidity to oxygen, when acted on by nitric acid, decomposes both the acid itself and the water present, attracting the oxygen of both. The acid is a compound of oxygen and nitrogen: when it suffers this decomposition its nitrogen is disengaged, at the same time the hydrogen of the water is liberated; and these two being presented to each other in the moment of their evolution, and before they have become elastic, (in their *nascent state*, as it has been named,) their mutual affinity is exerted with effect, and they combine; ammonia is thus produced. Dr Austin farther found, that it was sufficient to present hydrogen in its nascent state to nitrogen gas to form ammonia, this result being obtained when iron-filings moistened with water are confined in a tube with nitrogen gas over quicksilver. A similar production of ammonia has been observed to take place when nitric acid is acted on by phosphorus; that inflammable attract-



ing at the same time oxygen from the acid and hydrogen from the water, and the evolved nitrogen and hydrogen uniting in the moment of their disengagement.

The discovery of the existence of oxygen, as a constituent principle of the other two alkalis, potash and soda, suggested the conjecture, that it might exist as an element in the composition of ammonia. Sir H. Davy stated several experiments by which this appeared to be proved, and from which he inferred, that the proportion of oxygen in the composition of ammonia cannot be estimated at less than seven or eight parts in the hundred, and may even be larger. But the reverse was established by the experiments of other chemists. Dr Henry, submitting ammonia to analysis by the action of electricity, found, when the due precautions have been observed to exclude moisture, that it is resolved into hydrogen and nitrogen alone, without any trace of oxygen. The analogical inference, that ammonia must contain oxygen, from the fact, that all other bases which neutralize acids contain that element, has even led some to conclude that oxygen must exist either in hydrogen or nitrogen. This supposition, however, has no support from experimental investigation.

It may be remarked, however, that some experimental results have been obtained, which seem to indicate that ammonia, like the other alkalis, is a compound of oxygen with a metallic base. The supposed indications of this base have been observed, in submitting the alkali to the powerful decomposing agency of galvanic electricity. Ammonia itself is not easily subjected to the action of galvanism, but an ingenious form of experiment was employed by Seebeck, that of placing it in the galvanic circuit in contact with quicksilver. A globule of quicksilver was placed in a solid piece of carbonate or muriate of ammonia, slightly moistened, in connection with the positive



side of a galvanic battery, or, according to the method of Berzelius and Pontin, it may be placed in contact with a solution of pure ammonia in a platina spoon. On establishing the contact with a wire from the negative side, the quicksilver begins to increase in volume; it thickens and becomes less mobile, and at length is enlarged to four or five times its original volume, and becomes a soft solid, retaining the metallic lustre: oxygen is at the same time evolved at the positive wire. The changes the quicksilver thus suffers are similar to what would be produced from the communication to it of metallic matter. Hence it was concluded, that in the experiment the ammonia suffers decomposition, probably by the abstraction of oxygen, and that its supposed metallic base, (Ammonium as it was named,) remains in combination with the quicksilver. This appeared to be confirmed by the fact, that when the ammoniacal amalgam, as this soft solid has been named, is dropt into water, it is resolved into quicksilver and ammonia, hydrogen gas being evolved, which was supposed to indicate a decomposition of water, and the transfer of its oxygen to the ammonium, so as to reproduce ammonia. This amalgam, at a temperature of  $32^{\circ}$ , acquires considerable hardness, and even crystallizes in distinct and regular cubes.

The theory of this singular experiment has now been elucidated. Gay-Lussac and Thenard have shewn that this soft metallic solid is a compound of quicksilver with portions of ammonia and hydrogen, or an ammoniacal hydruret of mercury. In its production, the water with which the ammoniacal salt is moistened, and the presence of which is essential to the success of the experiment, is decomposed: its oxygen is attracted to the positive galvanic pole, while the hydrogen of the decomposed water, and a portion of the ammonia attracted to the negative



side, enter into weak combination with the quicksilver, dilating it, and diminishing its specific gravity. And they found, what establishes this view, that the ammoniacal amalgam, by exposure to heat, or by mere agitation when it is removed from the galvanic influence, is resolved into quicksilver, ammonia, and hydrogen, without oxygen being communicated to it from any source. Ammonia is thus the only alkali that does not contain oxygen\*.

The proportions of nitrogen and hydrogen which form ammonia, according to very careful experiments made by Dr Henry, are precisely 3 volumes of hydrogen and 1 of nitrogen, in conformity with the usual simple law of volumes. As each volume of these gases represents an atom, ammonia may be stated to be constituted of 3 atoms of hydrogen, 3, and 1 of nitrogen, 14; and its equivalent is therefore 17. The two gases in combining suffer a condensation equal to half their united volumes. The specific gravity of gaseous ammonia is, therefore, not equal to that of nitrogen, .9722, added to thrice that of

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\* This anomaly, which has appeared to chemists so perplexing, may be explained with facility, and without improbable suppositions, on Dr Murray's view of the causes producing acidity, (stated at p. 499). Acidity he inferred to arise exclusively from the agency of one or other of the two important principles, oxygen and hydrogen; sometimes one of these acting alone and independently, as the acidifying power; sometimes the other; and in the more powerful acids, both acting in conjunction. The same view, he remarked, may be extended to the alkalis. Oxygen confers alkalinity on bodies as well as acidity. Hydrogen communicates the latter: there is, therefore, no reason to conclude, that it may not also communicate the former. Ammonia is therefore an alkali, standing in the same relation to the other alkalis that sulphuretted hydrogen does to the acids,—nitrogen its base, and hydrogen its alkaline principle. Ed.



hydrogen, .2083, but to half this number, or .59027. From the condensation being thus only to two volumes, instead of to one, ammoniacal gas, like nitric oxide and muriatic acid gases, is an exception to the law of Dr Prout, that the specific gravity is equal to the atomic weight multiplied by .555. From the same reason, an atom of ammonia is not, as in most gases, represented by a volume, but as, in other four gases, nitric oxide, muriatic acid, prussic acid and hydriodic acid, is equivalent to two volumes. From its state of condensation, when ammoniacal gas is decomposed by the electric spark, and converted into hydrogen and nitrogen gases, it is doubled in volume.

Ammonia is always procured by indirect processes. Its ultimate source is usually from the decomposition of animal matter, of which its constituent principles are elements, and which, in the new combinations taking place in that decomposition, unite so as to form it. It is thus obtained abundantly in the distillation of bones and other animal substances. Procured in this way, however, it is always impure, and the chemist therefore usually avails himself of a salt containing it, prepared on a large scale for different purposes in the arts, the muriate of ammonia, or sal-ammoniac of commerce, from which it is easily obtained pure. This salt consists of muriatic acid, combined with ammonia. On mixing two parts of it with three parts of slaked lime, the pungent smell of ammonia is immediately apparent; and on applying heat to the mixture in a retort, there is an abundant production of gaseous ammonia, the calcium of the lime combining with the chlorine of the muriatic acid, and the oxygen of the lime uniting with the hydrogen of the acid: chloride of calcium and water are thus formed, and ammonia is disengaged. The ammoniacal gas must be received over



quicksilver, as it is instantly absorbed by water. So strong, indeed, is its attraction to humidity, that it is difficult to obtain the gas dry; one object in using an excess of lime is to absorb the water produced in the decomposition, and it is advantageous to use even a larger quantity of lime. To dry the gas thoroughly, it should be exposed to the action of fused potash; chloride of calcium can scarcely be used, as it absorbs the gas.

Ammonia, in the state of gas, has an odour extremely pungent, and is so acrid as to inflame the skin. It is one of the rarest of the elastic fluids, being, as has been stated, little more than half as heavy as atmospheric air. 100 cubic inches weigh 18 grains. It is permanently elastic at natural temperatures, but when exposed to a cold of  $-56^{\circ}$  of Fahrenheit, it is said to condense into the liquid state, probably from the presence of a small portion of water. The dry gas has been reduced, however, to the fluid form, by Mr Faraday, by evolving it in close glass tubes. To obtain it dry, advantage was taken of a peculiar property belonging to chloride of silver. This substance, when immersed in ammoniacal gas, is found to absorb a large quantity of it, 100 grains of the chloride condensing no less than 130 cubic inches; the compound thus formed is decomposed at a temperature of  $100^{\circ}$ . A quantity of it was placed in one leg of a bent glass tube, which was then hermetically sealed and heated; the other leg was cooled by the application of ice. Ammoniacal gas was evolved, and part of it, by the pressure of the elasticity of the remainder, was reduced to the liquid state. Thus condensed, it formed a colourless transparent fluid, of the specific gravity of .76 to water as 1; superior in refractive power to any of the other condensed gases, and to water itself. The pressure of vapour, which had thus rendered it fluid, was found to be equal to six atmospheres and a half at the temperature of  $50^{\circ}$ .



Gaseous ammonia extinguishes combustion; it is inflammable when previously mingled with atmospheric air, burning with a slight lambent flame; when kindled in mixture with oxygen gas it burns more strongly.

Ammoniacal gas is largely and rapidly absorbed by water; the water, under a mean atmospheric pressure and temperature, taking up, according to Sir H. Davy, 670 times its bulk of the gas, and acquiring a specific gravity of .875: according to Dr Thomson, water takes up even 780 times its bulk of ammoniacal gas. Ice immediately liquefies in the gas, at the same time condenses it, and this is accompanied by the production of cold. Its solution in water is of inferior specific gravity to pure water, being usually from .900 to .936. The gas is expelled from it by an elevation of temperature of  $130^{\circ}$ ; by intense cold the solution is congealed without the ammonia being separated: the congelation takes place at  $-40^{\circ}$ ; and at  $-50^{\circ}$  it loses all smell.

It is under the form of the watery solution that ammonia is usually employed as a chemical agent. The solution is prepared, according to the directions of the Edinburgh Pharmacopœia, by mixing 3 parts of newly slaked lime with 2 of muriate of ammonia reduced to powder, heating the mixture in a retort placed in a sand-bath, and connected with a receiver, in which a quantity of distilled water is placed, equal in weight to the salt employed. The ammoniacal gas which is generated passes over to the receiver, and is condensed by the water there. This process is intended to yield a very strong solution, but it will be found advantageous to place likewise in the retort a quantity of water equal to the weight of the salt. Mr Phillips has objected to this process, that the quantity of lime is unnecessarily large, whence large vessels are required; but Dr Hope considers this excess to be use-



ful, as accelerating the evolution of the ammoniacal gas, and hence rendering less heat necessary. The principle of employing an excess of the decomposing agent is in accordance with just scientific views, and it is frequently advantageous to use more than the requisite quantity of the cheaper material. On these grounds, the Edinburgh process may be regarded as the most economical, though perhaps the quantity of lime is rather large; Mr Phillips having found it to succeed better when equal weights of lime and salt were used. There is one disadvantage, however, attending the method, that the lime put into the retort is liable to become a solid mass, which cannot be removed without much trouble, and at the risk of breaking the retort. To remedy this, an improvement has been introduced by the London College: they direct three parts of lime and four of the salt to be mixed with nearly four times their weight of warm water; the liquor, when cold, to be filtered, and one-fourth of its weight to be distilled from it. It might scarcely have been *a priori* expected, that a sufficient quantity of lime would enter into combination with the acid and ammonia to retain the acid, and allow the ammonia to escape when the heat is applied. That this does happen, is, however, proved by the success of the process, which thus avoids the inconvenience of a large residue of lime in the retort. Mr Phillips recommends, as a preferable form of it, to mix 9 ounces of calcined lime with half a pint of water, and after they have stood an hour, to add 12 ounces of sal-ammoniac with  $3\frac{1}{4}$  pints of boiling water. When cold, the liquor is filtered, and 20 ounces distilled from it. On a large scale, the distillation is carried on from an iron-still containing the muriate of ammonia and lime dry, to which the fire is directly applied, the still being connected with a spiral tin-tube placed in a refrigeratory, and with the



extremity of which a series of globular receivers is likewise connected. When properly prepared the solution is colourless, and has the pungency of the ammonia unaccompanied with any foetor.

Ammonia is decomposed by chlorine gas. Its hydrogen uniting with the latter forms muriatic acid, with which a portion of ammonia combines, and its nitrogen is liberated. If the two gases are dry, the mutual action is attended with inflammation. This alkali unites with sulphuretted hydrogen. When equal volumes of sulphuretted hydrogen and ammoniacal gases are mixed together, a thin soft deposit is formed on the sides of the vessel, which exhales a penetrating vapour when exposed to the air: by surrounding the vessel, during its formation, with a freezing mixture, it is obtained in white crystals. This seems to be the proper Hydro-sulphuret of Ammonia. Another combination, long known to chemists by the name of Fuming Liquor of Boyle, is prepared by exposing to heat in a retort a mixture of sulphur, lime and muriate of ammonia; a liquor distils over of a yellow colour, which has a sharp fetid odour, and exhales white vapours, when exposed to atmospheric air or oxygen gas.

Ammonia unites with all the acids forming neutral salts. It has been supposed to be inferior in alkaline powers to the other two alkalis, as they decompose the compounds it forms with the acids: this, however, is probably owing to its volatility. From its small combining weight, a given weight of it neutralizes larger quantities of the acids than the same weight of the other alkalis do.

The ammoniacal salts retain, in some degree, the properties of the base. They are all volatile, being sublimed generally at a heat of 3 or 400: by a red heat they are decomposed. They are all soluble and crystallizable, and have an acrid taste. They are distinguished by the pun-



gent odour they exhale when triturated with lime, and by their throwing down an orange-yellow precipitate from muriate of platina. In conformity to the arrangement which has been adopted, these salts are to be considered in connection with their base.

CARBONATE AND BI-CARBONATE OF AMMONIA.—Ammonia, by combination with carbonic acid in different proportions, affords various products, in which, however, the alkali is not altogether neutralized. Though they exist in a concrete state, they are volatile, retain the pungent ammoniacal odour and taste, and change the vegetable colours to a green. The combination is easily established, by presenting the two gases to each other; they instantly unite and form a concrete salt: they unite in the proportions of 100 measures of the acid gas with 200 measures of ammoniacal gas, and the product of this combination used to be called a sub-carbonate; but as it consists of one atom of each ingredient, it is properly termed a carbonate. By dissolving this in water, and passing a current of carbonic acid through it, the bi-carbonate of ammonia is formed, containing two atoms of acid and one of ammonia.

Besides these, another of variable composition is usually met with in the shops, which has been called a sub-carbonate, but appears rather to be a sesqui-carbonate. The process followed for its production is an indirect one, decomposing muriate of ammonia by carbonate of potash or lime. Equal parts of chalk, dried, and of muriate of ammonia, are mixed together, and put into an earthen retort, or an iron-pot, to which a capital is adapted, and which is connected with a large receiver. Heat is applied; a double decomposition is effected, the lime attracting the muriatic acid, and the ammonia, the carbonic acid.



The sesqui-carbonate of ammonia being volatilized, is condensed on the sides of the receiver in the form of a crust. Sometimes it is obtained by another process in solution in water. Equal parts of muriate of ammonia and of carbonate of potash are put into a retort with two parts of water, and heat is applied; a double decomposition likewise takes place in this case, the muriatic acid uniting with the potash, and the carbonic acid with the ammonia; the carbonate of ammonia passes over with the aqueous vapour, which, when condensed, is sufficient to dissolve it. Sesqui-carbonate of ammonia is also obtained in large quantity in the decomposition of animal matter by heat. It is thus procured from bones, and forms the impure product which has been named Salt of Hartshorn.

The composition of these products varies so much, that, according to their analysis by Davy, the quantity of ammonia is from 20 to 50 in 100 parts. In general, the sesqui-carbonate consists of one equivalent and a half of acid, with one of ammonia and one of water. The numbers will be found in the Table at the end of this chapter.

Sesqui-carbonate of ammonia is very soluble in water; at 60° it requires only twice its weight, and at 212° less than its own weight is sufficient for its solution. Its saturated solution deposits crystals, the figure of which appears to be octohedral. Exposed to a very moderate heat it is volatilized, but is easily condensed, and its decomposition on the sides of the vessel is of a regular dendritical form. It effloresces on exposure to the air, and its odour becomes weaker, from the loss of part of its ammonia; and it even at last becomes a bi-carbonate. This salt is used in medicine as a stimulant and diaphoretic, and as a stimulating perfume. The bi-carbonate is comparatively mild.



**NITRATE OF AMMONIA.** This salt, prepared by adding carbonate of ammonia to dilute nitric acid, and evaporating the solution, crystallizes in slender four-sided prisms, or, if the solution has been more concentrated, in indistinct crystals, which form a compact mass, retaining less water of crystallization than the more regular crystals. Its taste is cool and bitter; it is deliquescent, and soluble in two parts of cold water, and half its weight of boiling water. It undergoes the watery fusion, from a moderate heat, and the water of crystallization is expelled; if the heat is increased, it is decomposed; and if raised to ignition, there is detonation from the combination of the oxygen of the acid with the hydrogen of the ammonia. This happens at temperatures above  $600^{\circ}$ : at temperatures between  $300^{\circ}$  and  $500^{\circ}$ , the decomposition proceeds more slowly; the products are nitrous oxide and watery vapour, and it is from this decomposition that nitrous oxide is obtained in its purest form: the salt is used only for procuring this gas.

**SULPHATE OF AMMONIA** crystallizes in slender six-sided prisms acuminated by six planes. It is soluble in about two parts of water at  $60^{\circ}$ , and in an equal weight of boiling water: is slightly efflorescent. Exposed to heat it melts and is decomposed, part of the ammonia being exhaled; at ignition its acid is decomposed. **SULPHITE OF AMMONIA** requires less than its own weight of boiling water for its solution, and the solution crystallizes on cooling; its crystals being transparent six-sided prisms. **HYPÓSULPHITE OF AMMONIA**, according to Mr Herschell, is composed of two proportions of acid to one of base. It has a pungent taste, and does not readily crystallize. When heated, it burns with a feeble flame, and entirely disappears.

**PHOSPHATE OF AMMONIA** is soluble in four parts of



water at the temperature of  $60^{\circ}$ ; it crystallizes in prisms. By exposure to heat, it is fused into a transparent glass, and decomposed, part of its ammonia being expelled. Heated with charcoal, its acid suffers decomposition, its oxygen being abstracted, which is not the case with the other phosphates. Like phosphate of soda, it may be used with advantage in analyses by the blowpipe. Phosphate of soda and ammonia, formerly called Microcosmic salt, is a triple salt of definite composition, consisting of one atom of phosphate of soda, 60, one of phosphate of ammonia, 45, and no less than 16 atoms of water when crystallized; its equivalent is hence 250. It is crystallizable, abundantly soluble in water, and very fusible.

PHOSPHITE OF AMMONIA has a strong penetrating taste; crystallizes in minute spiculæ. Exposed to the blowpipe it is decomposed, with the disengagement of phosphuretted hydrogen. HYPOPHOSPHITE OF AMMONIA is very soluble in water and in alcohol. BORATE OF AMMONIA is obtained by evaporation of its solution in prismatic crystals, of a sharp taste, and which change the vegetable colours to a green.

MURIATE OF AMMONIA.—This is the sal-ammoniac of commerce, an important salt from the uses to which it is applied; it is generally prepared on a large scale by indirect processes. A manufacture of it has been carried on in Egypt from time immemorial. It is there procured chiefly by sublimation from the soot of camels' dung. Large quantities of it have been prepared in Europe for a number of years past, so that the Egyptian sal-ammoniac is no longer imported. The processes followed in this country are various, but, in general, the first step is to procure a sulphate of ammonia, either by macerating soot, (which contains that salt in water,) or by directly combining sulphuric acid with impure ammonia, obtained



by distilling animal substances. When the sulphate of ammonia is prepared, it is mixed with muriate of soda, and heat applied. The sulphuric acid unites with the soda, and the muriatic acid with the ammonia, forming muriate of ammonia, which, from its volatility, is sublimed. This decomposition is sometimes effected in the humid way, by boiling solutions of the salts, crystallizing the sulphate of soda, and obtaining the sal-ammoniac by evaporation to dryness: sometimes muriatic acid is disengaged from salt by sulphuric acid, and directly combined with impure ammonia. From the manner of its preparation by sublimation in globular vessels, sal-ammoniac is obtained in large semi-spherical cakes of a crystalline structure. By solution in boiling water and cooling it may be crystallized, its crystals being four-sided prisms. It is soluble in  $3\frac{1}{2}$  parts of water at  $60^{\circ}$ , and in its own weight of boiling water. It is not deliquescent when pure, or at least only slightly so in a humid atmosphere: it is easily volatilized by heat. It is used in several of the arts, as in soldering metals, to clean their surfaces which are to be united, and to prevent oxidation: in dyeing, it renders several colours brighter; and it is from this salt that ammonia is usually procured. Its composition is easily shown by direct formation; and it will be found that equal volumes of muriatic acid and ammoniacal gases combine to produce it; or it consists of one atom of acid, 37, and one of ammonia, 17; its equivalent is therefore 54\*.

CHLORATE OF AMMONIA is formed by decomposing carbonate of ammonia by chlorate of lime: it crystallizes in needles; is very soluble in water and in alcohol, and is easily decomposed by heat.

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\* On the old theory of the nature of muriatic acid, this salt contains 16.7 parts in the hundred of water derived from the acid.



FLUATE OF AMMONIA has a very sharp taste, is volatile and easily decomposed. The FLUO-BORATES OF AMMONIA have been already noticed.

HYDRIODATE OF AMMONIA consists of equal volumes of the two gases ; it is soluble and deliquescent ; it crystallizes in cubes.

IODATE OF AMMONIA is calculated to consist of two volumes of ammoniacal gas, one of iodine, and two and a half of oxygen gas. It detonates on burning fuel, giving out a purple light and vapours of iodine. It is decomposed by heat, and gives iodine, oxygen and nitrogen.

The following table, collected from the best authorities, exhibits the composition of most of the ammoniacal salts. To render it more complete, the saline compounds which ammonia forms with the three or four metallic acids, and the vegetable acids that will be afterwards described, are inserted. The first column exhibits the atomic weights of the acids which exist in the compounds, according to the scale in which hydrogen is unity, each number representing one atom, except where the syllable *bi* is prefixed, indicating two equivalents of acid, or the term *sesqui*, denoting one equivalent and a half of acid. The second column shows the weight of base in the salt, or an atom of ammonia ; the third, the weight of water of crystallization often present ; and the fourth, the whole atomic weight of each salt.



## SALTS OF AMMONIA.

	Ammonia 1 atom = 17.	Acid.	Water.	Atomic Weight of the Salt.
Acetate, .....	17	50		67
Crystall. 7 atoms of water, .....	17	50	63	130
Arseniate, .....	17	62		79
Binarseniate, Cryst. 2 water, .....	17	124	18	159
Benzoate, Cryst. 1 water, .....	17	120	9	146
Borate, .....	17	24		41
Cryst. 2 water, .....	17	24	18	59
Carbonate, .....	17	22		39
Sesquicarbonate, 1 water, .....	17	33	9	59
Bi-carbonate, .....	17	44		61
Cryst. 1 water, .....	17	44	9	70
Chlorate, .....	17	76		93
Chromate, .....	17	52		69
Bi-chromate, .....	17	104		121
Cryst. 2 water, .....	17	104	18	139
Citrate, .....	17	58		75
Fluoborate, .....	17	34		51
Bi-fluoborate, .....	17	68		85
Sub-sesqui-fluoborate, .....	25.5	34		59.5
Bi-siliceo-fluate, .....	17	52		69
Hydriodate, .....	17	125		142
Iodate, .....	17	164		181
Molybdate, .....	17	72		89
Bi-molybdate, 1 water, .....	17	144	9	170
Muriate, .....	17	37		54
Nitrate, .....	17	54		71
Cryst. 1 water, .....	17	54	9	80
Oxalate, .....	17	36		53
Cryst. 2 water, .....	17	36	18	71
Binoxalate, .....	17	72		161
Phosphate, .....	17	28		45
Cryst. 2 water, .....	17	28	18	63
Bi-phosphate, .....	17	56		73
Phosphite, .....	17	20		37
Sacclactate, 1 water, .....	17	104	9	130
Succinate, .....	17	50		67
Cryst. 2 water, .....	17	50	18	85
Sulphate, .....	17	40		57
Cryst. 1 water, .....	17	40	9	66
Sulphite, .....	17	32		49
Tartrate, .....	17	66		83
Bi-tungstate, .....	17	300		317
2 water, .....	17	300	18	335



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CHAP. II.

## OF POTASH AND ITS BASE.

THIS alkali has long been employed in a state of greater or less purity as a chemical agent, and has been distinguished by various appellations. Being usually procured from the combustion of vegetables, it received the name of Vegetable Alkali. As it is the base of the impure alkaline salt, the potash of commerce, it has been named Potash. The term Potassa has been received as the Latin appellation, and is by some preferred in common language, as similar in termination to the names of the other alkalis; but that of Potash is the most generally used.

Potash had been suspected, from some analogies, to be a compound substance, but nothing was truly known with regard to its composition previous to Sir H. Davy's discovery of it,—a discovery which must be regarded as one of the most important in chemistry, both as having introduced to the knowledge of the chemist a class of substances possessed of very singular properties, and little analogous to any before known, and as having established views of extensive influence in the relations of the science.

This discovery of the constitution of potash was accomplished by the application of the powerful energy of galvanic electricity in subverting chemical combination, and causing the evolution of the elements of compounds in a separate state. The method in which this decomposition was most distinctly exhibited, was by placing a small piece of pure potash, slightly moistened, in a cup of platina, which was connected with the negative side of



a very large galvanic battery in a state of intense activity, and then bringing a platina wire from the positive side into contact with the upper side of the alkali. A vivid action was soon observed to take place, the potash melted, and an effervescence took place at its surface, owing to the disengagement of elastic fluid; while at the surface in communication with the negative side, there was no evolution of gas, but globules appeared having high metallic lustre, and similar to quicksilver. Some of these globules immediately took fire, and burnt with explosion, and a bright flame. The elastic fluid disengaged at the positive side, Sir H. Davy found to be oxygen gas. From these results, he inferred, that the potash had been decomposed; that the oxygen attracted to the positive pole was one of its elements; and that the metallic matter which appeared at the other pole was the base with which the oxygen had been combined. To this metallic base of the alkali, he accordingly gave the name of POTASSIUM.

These conclusions were established also by synthesis. On exposing the metallic-like matter to atmospheric air, its lustre is diminished, a white crust soon formed upon it, which was potash, and this was accompanied with an absorption of oxygen. On heating it in oxygen gas it entered into vivid combustion; solid potash was produced, and a portion of the oxygen was consumed. Or, on dropping it into water, an immediate disengagement of hydrogen gas took place, the potassium disappeared, and a solution of potash was obtained. From these experiments, no other conclusion seemed admissible, than that potash is a compound of this metallic matter and oxygen, since it is resolved into them, and is reproduced when they combine.

A confirmation of this discovery, important, as excluding any suspicion that might have been entertained, that



galvanic action is essential to these changes, was soon after made by the French chemists, Gay-Lussac and Thenard, potash having been decomposed by them by the action of iron; and as this method yields potassium in much greater quantity than can be obtained by the galvanic action even of very powerful batteries, it is usually employed in procuring this substance. Clean iron-filings are put into an iron tube, bent so that the filings shall lie in the curvature towards the middle of the tube. To one extremity of it is adapted, by grinding, a smaller tube having a stopper inserted at its open extremity, and containing a quantity of pure potash; the curved tube is placed across a small furnace, so that the iron-filings are raised to a white heat; the potash is then liquefied by applying to it the necessary degree of heat, and it is allowed to run through a small aperture on the filings. It suffers decomposition; the iron attracts its oxygen; and its base, the potassium, is sublimed to the other extremity of the tube, which is kept cold by a freezing mixture. A quantity of hydrogen gas is disengaged during the process, apparently derived from the water contained in the potash, and is allowed to escape by a tube of safety connected with the tube: it appears, by the affinity it exerts to the potassium, to assist greatly in separating it from the oxygen. The potassium adheres in brilliant plates to the sides of the extremity of the large tube, and when cold is detached. It is similar to that obtained from the decomposition of the alkali by galvanism, or, at least, is only a little heavier. The chief difficulty in performing this process is, to have the iron and potash perfectly pure, and to keep up the heat sufficiently without melting the tube. Some methods have been employed rather more simple, particularly one by Mr Tennant, in which solid potash and iron-filings are merely mixed together in the extre-



mity of a coated iron tube, and exposed to a high heat: the metallic matter is evolved and sublimed. Curaudu has also shown, that potash may be decomposed by the agency of charcoal; he mixed dry carbonate of potash with charcoal and linseed oil, and exposed the mixture to a strong heat in an iron tube, when potassium was sublimed, and might be collected. M. Brunner has shown, that the process may be rendered much easier, and more economical, if both charcoal and iron are used, as the potash will then be more completely decomposed and at a lower temperature; and he recommends also the substitution of carbonate of potash for caustic potash. Eight ounces of fused subcarbonate of potash, six of iron-filings, and two ounces of charcoal, heated in an iron bottle, gave 140 grains of potassium. It has been remarked, however, by Berzelius, that the potassium thus procured contains a small portion of carbon. When obtained, potassium must not be exposed to the air, as it will rapidly absorb oxygen and become potash; it is usually preserved immersed in naphtha, a very light fluid, which contains no oxygen.

Potassium, in its general properties, resembles a metal, yet it as well as the other alkaline bases that have been procured differ remarkably from the common metals in their inferior density, as well as in some other qualities. To distinguish them, the term Metalloid has been employed.

Gay-Lussac and Thenard proposed a theory of the production of potassium, and of its nature, different from that advanced by Sir H. Davy. When potash is acted on by galvanism, they supposed the water present to be decomposed; its oxygen to be evolved at the positive wire, or in the experiment with iron to combine with the iron, and its hydrogen to unite with the potash and form the



Potassium. When this substance is submitted to oxygenation, its hydrogen is supposed, in conformity to this view, to combine with the oxygen consumed, forming water, and the potash appears in its original state. And although the potassium may be produced without the presence of any sensible humidity, this does not invalidate this hypothesis, since even fused potash in its driest state contains a considerable quantity of combined water which will be decomposed. It followed, however, from this view, that potassium ought by oxygenation to form an alkali, containing a large quantity of combined water; while, if potassium be the base of potash forming it by oxygenation, the product of this oxygenation must be the real alkali free from water. From experimental researches on this point, it appears, that the product of the oxygenation of potassium does not contain such a quantity of water as is contained in fused potash. Gay-Lussac and Thenard have, therefore, relinquished the hypothesis.

Another view of this subject, however, which I proposed, may still be maintained, and seems indeed to be indicated by the phenomena connected with the production of potassium. Potash may be regarded, as at present, as a compound of a metallic base with hydrogen; but the substance obtained from its composition, which we call potassium, may not be this real base, but a compound of it with hydrogen. When fused potash is submitted to galvanic action, an effervescence is perceived at the positive galvanic wire from the evolution of oxygen gas; but there is no disengagement of gas at the negative wire, there is merely the production of the globules of potassium. These are the phenomena that ought to appear on the hypothesis that potash is an oxide of potassium, and that fused potash is the real alkali. But fused potash is not so;

Oxygen?



it contains nearly one-sixth of its weight of combined water, (consisting in general of one atom of real potash, 48, and one of water, 9): when submitted to galvanic action, this water must suffer decomposition; its oxygen will, in conformity to the usual law, be given out at the positive side; its hydrogen will be given out at the negative side; and being twice the volume of the oxygen, its evolution ought to be apparent. Since it does not appear, it may be inferred, that it enters into the composition of the real metallic base of potash, which will also appear at the negative side, and the potassium may be the product of this combination,—not a true metal, but a metallic hydruret, or compound of a metal with hydrogen. The experimental evidence by which this conclusion is to be established, is to determine whether potassium by oxygenation forms a product equal or inferior in alkaline strength to the real alkali, ascertaining the strength of the latter by making due allowance for the quantity of combined water which fused potash contains. The result of the experiments I have made on this subject is, that the potash formed by the oxygenation of potassium, though superior in alkaline strength to fused potash, is not equal to real potash; it must therefore contain a portion of combined water, and hence potassium probably must contain a proportion of hydrogen united with the real metallic base. As carbon, sulphur, and other inflammables, form compounds with metals, in which the metallic lustre and other characteristic qualities are not impaired, there is no improbability in hydrogen also forming compounds with metals, and which may retain much of the metallic appearance. Hydrogen, it may be remarked, in confirmation of this opinion, is known to have an affinity to potassium, and to combine with it even in several proportions. This view of the constitution of potassium accounts



for its peculiar qualities, and particularly for its great levity, a quality in which it differs so remarkably from metals, and which may be supposed to arise from the presence of hydrogen. A similar view may be extended to sodium, and perhaps to the metallic products from the earths\*.

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\* This opinion, advanced by Dr Murray, that potassium is a compound of the real metallic base of potash with hydrogen, is one highly interesting, as tending to explain one of the most anomalous facts in chemistry,—the contrast presented by potassium and its analogous metalloids to the metals in some of their properties, while they agree with them in so many other characters. It may perhaps be objected to this view, that no such quantity of hydrogen has ever been distinctly proved to exist in potassium, nor has ever been obtained from it. But, as has been remarked by Mr Faraday, in his examination of the compounds of carbon, iodine, and hydrogen, the atomic weight of hydrogen is so small, that when the equivalent of the other substance is large, (and that of potassium is not less than 40,) it is very difficult to detect or disprove the existence of one proportional of hydrogen in such compounds. However, in Dr Thomson's late valuable treatise, (First Princ. i. p. 255) results are stated, as obtained by Gay-Lussac and Thenard, and by himself, which are strongly in favour of Dr Murray's view. From the combinations into which potash enters, its atomic weight can be determined with perfect certainty; it is 48; hence, if we deduct 8 from this, being an equivalent of oxygen, there will remain 40, which must be the precise atomic weight of the real metallic base of potash. But the experiments of the French chemists, in which water was decomposed by *potassium*, gave for the atomic weight of that body, in reference to hydrogen as unity, the number 40.968, which is exceedingly near 41. Now, as an atom of hydrogen is equal to 1, this is a strong presumption that potassium is not the real radical, but consists of one atom of it, 40, and one atom of hydrogen, 1. Dr Thomson states, that his results were similar to those of Gay-Lussac and Thenard, the quantity of hydrogen evol-



It remains to state the properties of POTASSIUM. It appears in the form of globules, having metallic lustre and opacity at the temperature of  $60^{\circ}$ , similar in appearance to those of quicksilver, but less mobile. At  $70^{\circ}$  the mobility and fluidity are greater, and at  $100^{\circ}$  or  $136^{\circ}$  it is completely liquid, so that the globules run easily together. At  $50^{\circ}$  it becomes solid, is similar in appearance to silver, and is malleable: at  $32^{\circ}$  it is hard and brittle; and when viewed by the microscope, appears crystallized in brilliant white plates. Though it resembles the metals in opacity, lustre, and other properties, it differs from

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ved, when water is decomposed by potassium, being less than it should be, if it were the real base of the alkali. The experiments of these able chemists thus agree with those made by Dr Murray; and, when the difficulty is considered of detecting a single atom of hydrogen, give much probability to his opinion. Different results have indeed been obtained by Berzelius, but in an indirect and complicated manner, and one therefore more liable to error. Dr Thomson proposes to reduce the number to 40, considering the excess above this to arise from error; but 40.968 is certainly greatly nigher to 41 than to 40. It may be remarked, that if 41 be regarded as the more probable number, it will be almost a demonstration that hydrogen exists in potassium; for the equivalent of the real base must undoubtedly be 40, and the additional 1 can indicate no other body than hydrogen, none having an equivalent nearly so low. It may lastly be observed, that even if it shall be clearly proved, that an equivalent of hydrogen does not exist in potassium, it is possible that a less proportion may, namely, that two atoms of potassium may be united with one of hydrogen; and even this proportion may explain the non-appearance of the gas in the decomposition of hydrate of potash, and the peculiar and anomalous characters of potassium. The same view may be extended to sodium; but as it appears to have less affinity to hydrogen, it is probably combined with only a small proportion of that gas; accordingly sodium is considerably heavier than potassium. ED.



them remarkably in density : in this property it is inferior even to water or alcohol. Sir H. Davy found, that when liquid it does not sink in naphtha, the specific gravity of which is 0.77 : in its solid state it is rather heavier ; but still even at  $40^{\circ}$  it floats in this liquid : its specific gravity, therefore, cannot be greater than 0.7 or 0.8, water being 1 ; according to Gay-Lussac, however, it is 0.86. Potassium, though so easily fused by heat, is not very volatile ; it requires a temperature approaching to ignition to volatilize it.

The chemical relations of this substance are not less singular than its physical properties. It combines with oxygen slowly, and without any sensible combustion, at temperatures below that at which it is volatilized ; and, indeed, according to Thenard, it is the only metal acted on by perfectly dry oxygen gas : when heated in that gas to the point of volatilization, it burns vividly with intense heat and light. It unites with different proportions of oxygen. The product of its combustion is a solid white mass, which Sir H. Davy inferred to be potash. When it is gently heated in oxygen gas, so as not to inflame, a solid of a greyish colour is formed, which he considered as consisting partly of potash, and partly of potassium, in a low degree of oxidation. On the contrary, Gay-Lussac and Thenard have proved, that the substance formed by the combustion of potassium is not potash, but a product at a higher degree of oxidation, containing three times the quantity of oxygen which potash contains ; or it consists of one atom of the base, 40, and three of oxygen, 24 ; and its equivalent is therefore 64 : it is of a yellow colour, and is fusible : when water is added to it, there is an effervescence, from the disengagement of oxygen, and it is converted into potash : it also yields oxygen to inflammable bodies. The degree of oxidation of potassium which forms potash, appears to



be established almost exclusively by the agency of water; the proportion of oxygen with which the potassium combines is about 20 with 100 parts: hence potash consists of one atom of its metallic base, 40, and one of oxygen, 8, and its equivalent is 48. There is, lastly, a product obtained from the oxygenation of potassium, by inclosing it for some days in a small vessel loosely covered, which is dull, brittle, and inflammable; it appears, like that obtained by Sir H. Davy, to be a mixture of potash and potassium.

From its strong attraction to oxygen, potassium acts with energy on water, presenting the striking phenomenon of a body taking fire when dropt upon water; the water is rapidly decomposed; an explosion is produced with a bright flame; hydrogen gas is evolved; and the potassium is converted, by oxygenation, into potash. Placed on ice, it burns with a bright flame, melting the ice. It attracts oxygen, with similar rapidity, from the mineral acids, and burns. With the aid of heat, potassium can abstract oxygen from almost every substance containing it, and also from various oxidated substances. It thus changes the constitution of the other alkalis and earths. Its action on ammonia is singular. When heated in it, the ammonia disappears, hydrogen gas in a similar volume is produced, and an olive-coloured substance is formed, considered by Gay-Lussac and Thenard to be a compound of potassium with nitrogen and ammonia.

Potassium burns, when heated in chlorine gas, with a vivid flame; a chloride of potassium is the result; it is the same substance as muriate of potash when dried; and as its chemical properties can be known only when it is in the state of solution, as muriate of potash, a separate description of it is unnecessary. In like manner, when iodine and potassium are heated together, they unite with



an evolution of light, an iodide of potassium being formed, which is the same with dried hydriodate of potash.

Potassium unites with inflammable substances. When heated in hydrogen gas, it is dissolved: and the gas, on being mingled with atmospheric air, explodes with a vivid light, and the production of alkaline fumes. If a more gentle heat be applied, a solid compound containing a smaller proportion of hydrogen is formed: this hydruret of potassium is of a grey colour, without metallic lustre, and not inflammable at common temperatures. With phosphorus, a compound is formed, inflammable, and which has the appearance of the metallic phosphurets; and a second, a sub-phosphuret, of a chocolate colour, composed of two atoms of potassium and one of phosphorus.

When potassium is heated with sulphur, under the vapour of naphtha, they combine rapidly with the evolution of heat and light, and form a substance of a grey colour, with the lustre and appearance of artificial sulphuret of iron.

Sulphuret of potassium has also been obtained by M. Berthier, in the manner which has been already mentioned, by inclosing sulphate of potash in a crucible lined with charcoal, defending it from the contact of the air, and exposing it to a white heat for an hour or two. The sulphuret of potassium, thus procured, was in a mammillary crystalline mass, of a fine flesh red colour, and translucent. When thrown into water, it was dissolved, producing a considerable elevation of temperature. While it was mixed with the charcoal in the crucible, it took fire, upon being moistened,—a fact which enables us to explain the spontaneous inflammation of pyrophorus, a mixture supposed to contain potassium, which will be afterwards mentioned. In dissolving in water, it is in-



ferred that it passes to the state of a hydro-sulphuret of potash, the potassium attracting oxygen from the water present to become potash, and the sulphur uniting with the disengaged hydrogen to form sulphuretted hydrogen, which immediately combines with the potash. Hence, the addition of an acid at once disengages sulphuretted hydrogen. Sulphuret of potassium, it would appear, is composed of one atom of potassium, 40, and one of sulphur, 16; its equivalent will thus be 56. According to Berzelius, even five or six compounds of potassium in different proportions may be obtained by heating subcarbonate of potash out of contact of the air. Of five of these, the composition seems to be ascertained, and they appear to form a regular series.

Potassium also combines with the metals, and forms compounds having metallic properties, which absorb oxygen from the air and decompose water, potash being formed, and the other metal separated unchanged. Its action on quicksilver is singular. They instantly combine with the evolution of more or less heat: the potassium in a minute quantity adds to the consistence of the quicksilver, and diminishes its mobility: when the quantity is about 1-70th of the weight of the quicksilver, the amalgam is soft and malleable: in a quantity a little larger it renders it solid, and nearly similar to silver in colour: when it amounts to about 1-30th of the weight of the quicksilver, the alloy is hard and brittle. The fluid amalgam dissolves all the metals, even those, as platina, with which quicksilver alone does not combine. Compounds of the metals with potassium may likewise be formed by heating an excess of potassium with the metallic oxides, one portion of it abstracting oxygen and becoming potash, the other uniting with the reduced metal. From this action it decomposes and corrodes glass, reducing the oxides of



iron and lead which it contains, and forming potash, which dissolves the glass.

After this account of the properties of potassium, it remains to give the chemical history of POTASH.

Potash is usually procured from the combustion of land vegetables, the process being carried on in those countries which abound in wood. The ashes remaining after the combustion being lixiviated, the liquor affords, on evaporation, saline matter, the potashes of commerce; this, when exposed to heat, has a quantity of extractive matter burnt out, and loses a portion of water; it then becomes a white mass of a bluish tinge, which is the Pearl-ash of commerce. This consists of various salts, principally of potash combined with carbonic acid, partly also of potash combined with sulphuric and muriatic acids, together with silex, oxides of iron and manganese, and occasionally other impurities. The alkaline matter is obtained in different quantities from different vegetables: the harder woods afford more than those that are spongy, shrubs more than trees, herbaceous plants a quantity still larger, and even different parts of the same plant give different proportions of it; the leaves, from a given weight, yielding more than the branches, and the branches more than the trunk.

The alkali is sometimes procured from other sources, and in a state more pure, as from the decomposition by heat of the salt named Tartar, or the deflagration of nitre with charcoal.

Potash, as obtained by all these processes, is combined with carbonic acid. To abstract this, the saline matter, which used to be called Sub-carbonate of Potash, but is now more correctly termed Carbonate of Potash, is first freed from the other ingredients by lixiviation and evaporation of its solution, and is then mixed with more than



an equal weight of recently slaked lime, and as much water as is necessary to give the consistence of a thin paste: this is put into a glass funnel, the tube of which is obstructed with a piece of linen; the mass of lime soon subsides, so that the liquid portion filtrates through it slowly, and water is occasionally added, as the filtration proceeds, until a quantity of liquid has passed through, ten times the weight of the carbonate of potash employed. The lime in this process attracts the carbonic acid from the potash, and, from the large quantity employed, and the slowness with which the dissolved alkali passes through it, the abstraction is more complete than could be obtained by any other arrangement.

Still, the potash is not perfectly pure; a little carbonic acid remains combined with it, and there may also be present small portions of sulphate and muriate of potash and silex. To obtain it in a state of purity, the method generally followed is one proposed by Berthollet. Potash is soluble in alcohol, but is insoluble when combined with carbonic or sulphuric acid. The potash to be purified is therefore digested in alcohol, the impurities remain dissolved in water in a lower stratum, while the alcohol holding the pure alkali dissolved, floats above; this is drawn off, and is partially evaporated in a silver bason. The upper portion of the liquor is again poured off, and is evaporated, so that on cooling it shall either deposite crystals, or pass into an irregular crystallized mass; this is the pure potash. Still, even after these processes, so strong is its attraction to carbonic acid, and such the influence of quantity of matter, that it retains a minute portion of that acid, appearing even to abstract carbon from the alcohol. D'Arcet has recommended to add to its solution barytic water, which may render it perfectly pure.

Potash thus prepared is when dried a solid mass, hard,



and brittle, of a greyish-white colour. It may be obtained crystallized in thin plates, in slender needles, or in tetrahedral pyramids, single or double, these containing different portions of water of crystallization. They produce cold in dissolving in water, while the solid potash produces heat. Even in the driest form to which it is reduced by evaporation, and after it has been kept in fusion, the potash retains a considerable quantity of water combined with it, and which cannot be abstracted from it; as by applying heat to expel it, the potash itself is at length volatilized, along with its combined water, which is separated only when it enters into combinations. This important fact was discovered by D'Arcet. The quantity of water seems to be one atom, 9, to one atom of potash, 48; hence the equivalent of the compound, Hydrate of Potash, as it is called, is 57. The combined water gives rise to a considerable modification of properties. The real alkali is supposed to be obtained by the combustion of potassium, and heating the product, so as to expel the excess of oxygen. It is of a greyish colour, harder and heavier than fused potash, with a vitreous fracture; it requires a strong red heat to melt it, and a higher heat to volatilize it. When a little water is added to it, it becomes white and more fusible and volatile. It is uncertain what the properties of this compound are, whether it has any alkaline quality or not; for it cannot be submitted to examination without the admission of water, which immediately changes its composition, converting it into the hydrate. The hydrate melts at a heat of  $360^{\circ}$ , and is volatilized at a low red heat. It still has a strong attraction to an additional portion of water: it imbibes it rapidly from the atmosphere, so that its surface becomes humid, and it dissolves in less than its own weight of water, forming a solution dense and somewhat viscid.



Potash is an alkali of considerable strength : a minute portion of it changes the blue and purple colours of vegetables to a green, and it is so powerfully corrosive as quickly to erode and dissolve animal matter. It unites with oils and fats, forming soaps, which, though concrete, are soft and gelatinous. It combines with some of the metallic oxides ; it unites with some of the earths by fusion, and others are dissolved by its solution in water. Potash has the distinguishing alkaline property of combining with acids and neutralizing their properties : from its combining weight being high, however, its saturating power is not great. The best test for detecting its presence in a solution, is a solution of muriate of platina, which will throw down a yellow precipitate, the triple muriate of platina and potash.

Potash is acted on by phosphorus. When it is heated in a close tube with phosphorus, a compound is formed, which when thrown into water decomposes it, phosphoric acid remaining in solution, and phosphuretted hydrogen being liberated. The nature of this compound is yet uncertain ; it may either be a phosphuret of potash, or a mixture of phosphate of potash and phosphuret of potassium.

SULPHURET OF POTASH, it used to be imagined, is formed when equal parts of sulphur and dry concrete potash are heated in a covered crucible, or when one part of sulphur and two parts of sub-carbonate of potash are heated together. But, as has been stated, the usual product of these methods is sulphuret of potassium. It is said, however, that if the heat be kept moderate, a proper sulphuret of potash is formed. It is inodorous while dry ; but when moistened or dissolved, acquires a fetid smell from the production of sulphuretted hydrogen. From suffering decomposition when in a state of solution, it is scarcely possible to discover precisely its peculiar agencies.



HYDROSULPHURET OF POTASH is formed by transmitting sulphuretted hydrogen through a solution of potash. It is obtained in large prismatic crystals, white and transparent; its taste is alkaline and bitter. It attracts humidity from the air, and is soluble both in water and alcohol. SULPHURETTED HYDROSULPHURET OF POTASH is formed either when sulphur is boiled with hydrosulphuret of potash, or with a solution of potash. It is of a yellow colour, its taste acid and nauseous, has a soapy feel, and stains the cuticle black. The acids precipitate sulphur from it.

CARBONATE OF SUB-CARBONATE OF POTASH. — This salt, it has been stated, forms the base of the potashes and pearl-ash of commerce, obtained by the incineration of vegetables; it is necessarily mixed with many impurities. From these it is in part freed, by dissolving the pearl-ash in an equal weight of warm water; the foreign substances being sparingly soluble, remain in a great measure undissolved; the clear liquor is poured off, and is evaporated until a pellicle appear on its surface; on cooling and remaining at rest for a few hours, it deposits a little muriate of potash; and being poured off from this and evaporated, the carbonate is obtained. Other processes have been employed to procure it, such as burning tartar at a red heat: this substance consists of potash combined with tartaric acid,—a vegetable acid composed of oxygen, carbon, and hydrogen, which, when decomposed by heat, affords carbonic acid, and with this the potash combines. By deflagrating tartar with nitre, a similar product is formed, and also by deflagrating nitre with charcoal, the charcoal being converted into carbonic acid by the oxygen afforded by the decomposition of the nitric acid, and the carbonic acid combining with the potash, which is the base of the nitre. As obtained by these processes



the carbonate of potash is even purer than in the state in which it is procured from the pearl-ash of commerce. Carbonate of potash, obtained in a concrete state by evaporation, is in the form of coarse grains, as it is not susceptible of regular crystallization. From the predominance of the alkali in it, it is deliquescent; if exposed to the air it soon attracts as much water as dissolves it; it is soluble in less than its weight of water. Its taste is acrid; it changes the vegetable colours to a green, and combines with oils, forming a saponaceous compound. These characters are so distinctly alkaline, that they formerly led to the opinion, that the potash was in excess in the salt, and hence it was termed a sub-carbonate: they are, however, to be ascribed rather to the weak acidity of the carbonic acid, than to deficiency in its proportion; for it is proved, that the salt consists of one atom or equivalent of carbonic acid, 22, and one of potash, 48; hence it is strictly a carbonate of potash, and is now so termed; its equivalent is 70. The crystallized salt contains two proportionals of water; at  $280^{\circ}$  the whole of this is expelled, but the salt may be fused at a red heat, without losing any of its acid. It is decomposed by the acids; its carbonic acid being disengaged with effervescence.

BI-CARBONATE OF POTASH may be obtained by exposing the solution of the carbonate to the air for some time, carbonic acid being imbibed from the atmosphere, and crystals being deposited. Or it is formed more directly by passing a current of carbonic acid gas through a solution of the carbonate of such a strength that crystals form spontaneously. The crystals are bevelled quadrangular prisms; they do not, like the carbonate, deliquesce. They require four parts of water at  $60^{\circ}$  for their solution, and produce, while dissolving, a degree of cold. They are much more soluble in hot water, the water taking up even



5-6ths of its weight; but if the temperature be that of boiling water, part of the carbonic acid assumes the elastic state, and rises through the liquor. The taste of this crystallized salt is more mild than that of the sub-carbonate; though still alkaline it has no causticity, but it changes the vegetable colours to a green: the alkaline qualities are thus not neutralized, even by an excess of carbonic acid. Dr Wollaston shewed, that it contains just double the quantity of acid in the sub-carbonate; hence the name of Bi-carbonate which he gave it: two atoms of carbonic acid are 44, one of potash is 48, and a proportional of water, 9, also exists in it; its equivalent is therefore 101. It is used for some medicinal purposes. Solution of potash may be supersaturated with carbonic acid by dissolving the carbonate in water, (one ounce in ten pounds,) and by the assistance of cold and pressure impregnating the solution strongly with carbonic acid gas; the liquor, when a sufficient quantity of carbonic acid has been combined in it, is pleasantly acidulous, with some pungency, and the alkali thus supersaturated proves less irritating to the stomach than in any other state.

NITRATE OF POTASH is the salt well known by the name of Nitre or Saltpetre. In warm climates it is, under certain circumstances, formed spontaneously at the surface of the soil; it is thus procured in India, whence the nitre we use is imported. In some countries of Europe, particularly France and Germany, the production of it is favoured by artificial arrangements. Vegetable and animal substances, with an intermixture of old plaster, mortar, or other forms of carbonate of lime, are put into ditches lined with clay, and covered with sheds to protect them from the rain, while the air is admitted. They are turned up occasionally, and at the end of a few months, when washed with water afford nitrates of potash and lime.



A quantity of wood-ashes is added to the solution, the potash of which decomposes the nitrate of lime, and increases the product of nitrate of potash; this salt is obtained in crystals by evaporation, and is purified from muriate of soda and other salts which adhere to it, by repeated solutions and crystallizations.

The nitre does not pre-exist in these materials, and is therefore obviously formed in the process. The most probable explanation is, that the nitrogen of the animal matter combines with the oxygen of the air, and perhaps with a portion of the oxygen of the vegetable matter, and forms the nitric acid: while the carbonate of lime favours this combination by the resulting affinity exerted by the lime, and by attracting the acid as it is formed. The vegetable matter moderates the decomposition of the animal substances, and prevents their running into that putrefaction by which the nitrogen is spent in the formation of ammonia; it may further afford part of the potash, which is the base of nitre. A certain degree of humidity favours the mutual actions whence these combinations arise, and diffuses more equally through the materials the nitrous salts.

Nitre crystallizes in six-sided prisms bevelled at the extremities; its taste is cool; it is soluble in seven parts of water at  $60^{\circ}$ , a production of cold attending its solution, and in an equal part of boiling water. It melts easily, and may be cast in moulds, forming what is called *Sal Prunelle*, which is of a more compact texture: if the heat be raised, a partial decomposition of the acid takes place, and oxygen gas is expelled; at the temperature of ignition, the decomposition is more complete, and oxygen and nitrogen gases are disengaged. The proportions of its elements are one atom or proportional of nitric acid, 54, and one of potash 48; its equivalent is therefore 102: it is anhydrous, or contains no water.



From its facility of decomposition by heat, nitre produces deflagration, when heated with inflammable bodies, as has been explained under the general theory of combustion. It is from this that it is the principal ingredient in the composition of gunpowder, which consists of 75 parts of it by weight with 16 of charcoal, and 10 of sulphur. These ingredients are thoroughly mixed by continued trituration, a small quantity of water being added to favour this; the paste into which the composition is at length brought is granulated by pressing it through a sieve, and the grains, after they are dry, are rounded and glazed by friction from agitation. The deflagration of the gunpowder, when an ignited spark falls on it, is owing to the rapid communication of the oxygen to the sulphur and the charcoal; and its great expansive force depends on the sudden extrication of the aërial products—sulphurous acid and carbonic acid formed by the oxygenation of the sulphur and charcoal, and nitrogen from the decomposition of the acid. These gases, when cold, occupy, it is found, 250 times the bulk of the powder from which they have been produced: but at the moment of explosion, when their elasticity is greatly increased by the high temperature, it is calculated that they must require 1000 times the volume of the powder; and as each of these volumes exerts a force equal to that of the atmosphere, or 15 pounds on the square inch, the total expansive force of gunpowder cannot be less than 15,000 pounds on a square inch. By this force a bullet, it is calculated, must be propelled from a gun with a velocity of about 2000 feet in the second. The chief use of the sulphur is, that the powder may be easily kindled, while the charcoal when inflamed burns with greater rapidity and a greater extrication of heat, and prevents the liquefaction of the whole mass. Another detonating composition, still more



powerful than gunpowder, of which nitre is the principal ingredient, is that named *Pulvis Fulminans*. It consists of three parts of nitre, two of carbonate of potash, and one of sulphur triturated together: when heated, it explodes with a very loud report. Its detonation appears to be owing to the formation of sulphuret of potash, which, re-acting on the water contained in the salts, disengages sulphuretted hydrogen, and this, presented in its nascent state to the oxygen of the nitre, forms sulphurous acid and watery vapour in a state of high elasticity from the caloric disengaged.

NITRITE OF POTASH seems to be formed when, by a certain degree of heat, an equivalent of oxygen is expelled from nitre; for even a weak vegetable acid, as the acetic, is then able to decompose the salt, evolving red nitrous acid fumes. It is supposed by some, however, that the salt is then rather in the state of a hyponitrite.

SULPHATE OF POTASH is formed by adding diluted sulphuric acid to a solution of carbonate of potash, until the acid and alkaline properties are neutralized. A more economical process, generally followed in pharmacy, is to prepare it from the residual mass obtained in the distillation of nitric acid from nitre and sulphuric acid; this is a bi-sulphate of potash, and by abstracting the excess of acid by lime, which forms an insoluble sulphate of lime, the neutral sulphate of potash results, which may be obtained by evaporation. The crystals of this salt are six-sided prisms with pyramidal terminations; it requires for its solution 17 parts of water at 60°, and five parts at 212°. Its taste is bitter: it consists of one atom of potash and one of acid.

BI-SULPHATE OF POTASH, or Super-sulphate of Potash, is the salt remaining after the decomposition of nitre by sulphuric acid. By solution and slow evaporation it can



be obtained in crystals. It consists of one atom of potash, 48, and two atoms of sulphuric acid, 80. It has a very sour taste, and reddens vegetable colours: it is much more soluble than the sulphate, requiring only two parts of water at  $60^{\circ}$ , and less than one part at  $212^{\circ}$ . **SULPHITE OF POTASH** is obtained in rhomboidal or acicular crystals, white and transparent, soluble in an equal weight of cold water. **HYPO-SULPHITE OF POTASH** is formed by exposing a solution of sulphuretted hydro-sulphuret of potash to the atmosphere till it loses its yellow colour. When this liquid is evaporated, the hypo-sulphite crystallizes in a confused mass of acicular crystals. It has a penetrating taste like nitre, and is very deliquescent. When the dry mass is heated it takes fire, and burns with a weak blue flame. **HYPO-SULPHATE OF POTASH** crystallizes in cylindrical prisms, terminated by a plane perpendicular to the axis: it has the property of dissolving chloride of silver.

**PHOSPHATE OF POTASH** can, according to Dr Thomson, be obtained in octohedral crystals, but usually forms a gelatinous mass, which attracts humidity from the atmosphere: its taste is saline, with a degree of sweetishness. Exposed to heat it liquefies, and after the expulsion of the water is fused by a red heat into a glass. Dr Thomson states that three definite compounds may be formed of phosphoric acid and potash; the neutral, consisting of an atom of acid, and one of base; the sub-phosphate composed of one atom of acid, and two of base; and the bi-phosphate containing one of base and two of acid. **PHOSPHITE OF POTASH** is formed by saturating phosphorous acid with potash. It is a neutral salt, very soluble in water, and crystallizes in four-sided prisms. It intumesces before the blowpipe with a phosphorescent light. **HYPO-PHOSPHITE OF POTASH** is very soluble in water, and more deliquescent even than the muriate of lime; it is also soluble in alcohol.



SUB-BORATE OF POTASH, like several other borates, contains an excess of alkali; it is soluble in water; by evaporation, its solution affords prismatic crystals, which are not changed by exposure to the air.

MURIATE OF POTASH has a taste saline and slightly bitter: it is soluble in 3 parts of cold, and in half its weight of boiling water, the latter solution crystallizing on cooling; the crystals have a cubic form, and decrepitate when heated, from the loss of water. As this water is dissipated, the nature of the substance changes; the oxygen of the potash, it is conceived, unites with the hydrogen of the acid; and when the mass is completely dried, it is no longer a salt, contains neither acid nor alkali, but is a chloride of potassium. The same substance is formed when potassium is burnt in chlorine gas: it is composed of one atom of chlorine, 36, and one of potassium, 40.

CHLORIDE OF POTASH must evidently be formed where chlorine is condensed by a dilute solution of potash, since the alkaline properties are neutralized. The liquid still retains the power of destroying vegetable colours. The compound, however, cannot be obtained insulated, as by concentration of the solution decomposition takes place, and a chlorate is formed.

CHLORATE OF POTASH.—To prepare this salt, a solution of potash is put into the bottles of Woolfe's apparatus, and a current of chlorine gas is passed through it, from a retort containing sea salt, sulphuric acid, and oxide of manganese: this is continued until the alkali is neutralized; the chlorate of potash is deposited in scales, while a portion of muriate of potash remains in solution; one portion therefore of the chlorine combines with the hydrogen of the water forming muriatic acid, while the rest of the chlorine, uniting with the oxygen of the decomposed water, becomes chloric acid. The two acids



uniting with the alkali, form chlorate and muriate of potash. Chlorate of potash crystallizes in scales, in needle-like crystals, or in thin quadrangular plates, white, and of a silvery lustre. It is soluble in 17 parts of water at  $60^{\circ}$ , and in  $2\frac{1}{2}$  parts at  $212^{\circ}$ ; it melts when heated; at a red heat it is decomposed, and very pure oxygen gas is expelled. 100 grains of the salt freed from water yield 38.5 of oxygen.

Besides, the old doctrine respecting chlorine, in which this salt was termed the hyper-oxy-muriate of potash, two opinions are at present entertained respecting it, even by the supporters of the new views. Sir H. Davy regards it as a triple compound of one atom of chlorine, one of potassium, and six atoms of oxygen. Gay-Lussac, again, whose opinion is generally followed, considers these atoms as disposed into acid and alkali, as in other salts; or that it is a compound of potash, consisting of one atom of oxygen, and one of potassium, with chloric acid, consisting of one atom of chlorine, and five of oxygen. On either view its equivalent is 124.

Chlorate of potash is decomposed by the acids. Thrown into sulphuric acid it decrepitates, the liquor acquires an orange colour, and a dense yellowish-green vapour is disengaged. If heat is applied, an explosion with a vivid flash of light takes place; if the acid be diluted so as to admit of the application of heat with safety, the elastic fluid which is disengaged is a mixture of chlorine and oxygen. Muriatic acid also decomposes the salt, and is at the same time converted into chlorine. The elastic fluid disengaged in these decompositions acts with considerable force on inflammable substances; two or three grains of the salt, for example, mixed with half the quantity of sulphur, charcoal, resins, or oil, forming mixtures which are kindled by sulphuric or nitric acid. In this way, a light may be



easily obtained at any time, by placing a few grains of chlorate of potash on a piece of paper, dropping a little oil of turpentine on them, and then adding a drop of strong sulphuric acid; the oil will be immediately inflamed, and will kindle the paper. The salt itself acts with still more energy on inflammable bodies. If a grain or two be triturated with half its weight of sulphur or charcoal, or if the mixture in these proportions be struck forcibly, a loud detonation is produced. A similar effect is produced when several of the metals are employed; and with phosphorus the detonation is so violent, that it can be made with safety, only on a very small quantity. These mixtures are also inflamed by the electric discharge, by applying heat, and frequently by acids. In the common match bottles for procuring a light, a mixture of this kind is employed: it consists of sugar triturated with half its weight of chlorate of potash, which is then made into a paste with mucilage, and sulphur matches dipt into it: the bottle into which they are dipt contains a portion of strong sulphuric acid, retained by fibres of amianthus, or of spun glass. The detonations of these mixtures appear to rise from the rapid combination of the oxygen of the salt with the inflammable body, and the formation in general of an elastic product.

PERCHLORATE OF POTASH is prepared by mixing one part of chlorate of potash with three of sulphuric acid, and exposing the mixture to heat till it turns white; bisulphate and perchlorate of potash are formed, the former of which may be washed away, as it is much more soluble in water. It is a neutral salt: heated with sulphuric acid to  $280^{\circ}$ , it yields perchloric acid; at a higher temperature it is resolved into oxygen and chloride of potassium.

FLUATE OF POTASH has a sharp taste, is deliquescent,



very soluble in water, and not easily crystallizable.—HYDRIODATE OF POTASH. This salt is very soluble in water; when dried it is decomposed, like the other hydriodates, and is converted into iodide of potassium, which is fused and volatilized at a red heat.—IODATE OF POTASH is soluble and crystallizable; it deflagrates when thrown on burning fuel.

From the numerous and powerful chemical actions which potash exerts, it is applied to many purposes of utility in the arts; and as it is the alkali most easily procured, it is the one most extensively used. It is thus employed in bleaching, dyeing, soap-making, the manufacture of glass, and others. In medicine it is employed as an antacid, a lithontriptic, and an escharotic.

Besides being produced in the vegetable, it is found in the mineral kingdom, either as a saline combination, or as an ingredient in some earthy fossils. It also exists in several of the animal fluids and solids.

The equivalents of the compounds of potassium and of potash, and the proportions of the constituents according to their different combining weights, in reference to hydrogen as 1, will be found in the following table :

## COMPOUNDS OF POTASSIUM.

	Potassium, 1 atom = 40.	Weight of the other body.	Atomic Weight of the com- pound.
Chloride, .....	40	36	76
Hydruret ? .....	40	1	41
Iodide, .....	40	124	164
Oxide, (Potash), .....	40	8	48
Peroxide, .....	40	24	64
Phosphuret, .....	40	12	52
Subphosphuret, .....	80 (2 at.)	12	92
Sulphuret, .....	40	16	56
Bi-sulphuret, .....	40	32	72
Tritosulphuret, .....	40	48	88
Quadrosulphuret, .....	40	64	104
Persulphuret, .....	40	80	120



## SALTS OF POTASH.

	Potassium. 1 atom = 48.	Acid.	Water. 1 atom = 9.	Atomic Weight of the Salt.
Acetate, .....	48	50		98
Binacetate, Cryst. 6 water, .....	48	100	54	202
Arsenate, .....	48	62		110
Binarsenate, .....	48	124		172
Cryst. 1 water, .....	48	124	9	181
Arsenite? .....	48	54		102
Benzoate, .....	48	120		168
Cryst. 3 water, .....	48	120	27	195
Carbonate, .....	48	22		70
Cryst. 2 water, .....	48	22	18	88
Bi-carbonate, .....	48	44		92
Cryst. 1 water, .....	48	44	9	101
Chlorate, .....	48	76		124
Chromate, .....	48	52		100
Bi-chromate, .....	48	104		152
Citrate, .....	48	58		106
Hydriodate, .....	48	125		173
Iodate, .....	48	164		212
Molybdate, .....	48	72		120
Nitrate, (nitre,) .....	48	54		102
Oxalate, .....	48	36		84
Cryst. 1 water, .....	48	36	9	93
Binoxalate, .....	48	72		120
Cryst. 2 water, .....	48	72	18	138
Quadroxalate, .....	48	144		192
Cryst. 7 water, .....	48	144	63	255
Perchlorate, .....	48	92		140
Phosphate, .....	48	28		76
Cryst. 1 water, .....	48	28	9	85
Bi-phosphate, .....	48	56		104
Succinate, .....	48	50		98
Sulphate, .....	48	40		88
Bi-sulphate, .....	48	80		128
Cryst. 2 water, .....	48	80	18	146
Sulphite, .....	48	32		80
Tartrate, .....	48	66		114
Cryst. 2 water, .....	48	66	18	132
Bi-tartrate, Cryst. 1 water, (cream of tartar,) .....	48	132	9	189
Tungstate, .....	48	150		198



## CHAP. III.

## OF SODA.

SODA being found more extensively diffused in the mineral kingdom than either of the other alkalis, has been denominated Mineral Alkali. The term Soda is that usually applied to it, and is unexceptionable.

On the discovery of the composition of potash, Sir H. Davy submitted soda to the same method of analysis, and discovered that it affords a base of a similar nature. It required for its decomposition rather a greater degree of galvanic power than potash did; but when this was applied in sufficient intensity, the phenomena were similar; an effervescence was produced at the positive side, which was found to arise from the disengagement of oxygen gas; and at the surface in contact with the negative wire, globules were produced having metallic lustre. This matter, exposed to the air, absorbed oxygen, and reproduced Soda: the same result took place more speedily, and with the phenomena of combustion, when it was heated in oxygen gas, or when dropt into water,—a solution of soda was formed, with an extrication of hydrogen gas. These results proved, that the soda was decomposed by the galvanism, that the oxygen disengaged at the positive pole is derived from it, and that the metallic matter which collects at the negative side, SODIUM, as it is named, is the base with which the oxygen had been combined. The same theory is probably to be adopted with regard to this as with regard to potassium; namely, that what we call sodium is a compound of the real base with hydrogen.



The process of Gay-Lussac and Thenard, of decomposing the alkali by iron, does not succeed so easily with soda as with potash : the easiest process for obtaining sodium is to decompose soda, by heating pure and dry sea-salt (chloride of sodium) with potassium : the potassium attracts the chlorine, and the sodium is sublimed. SODIUM is white and opaque, with metallic lustre, having the general appearance of silver ; it is very malleable, and is so soft, that with a slight force it can be extended in thin leaves,—a softness which it retains even when cooled to  $32^{\circ}$  : several globules may by pressure be forced into one, a property analogous to the welding of iron and of platinum. Though lighter than water, its density is greater than that of potassium ; Mr Davy estimates its specific gravity at .9348, Gay-Lussac at .97223. It requires a higher heat to melt it than potassium does : at  $120^{\circ}$  it begins to lose its cohesion ; at  $180^{\circ}$  it is fused : it is also less volatile, as it remains fixed even at ignition.

When exposed to the atmosphere it is oxidated, soda being formed on its surface, which deliquesces slowly. When heated nearly to ignition in atmospheric air, the combination is attended with combustion ; and when heated in oxygen gas it burns with a vivid white light, emitting bright sparks. Like potassium it combines with oxygen in different proportions. The protoxide is soda, which consists of one atom of sodium, 24, and one of oxygen, 8, its equivalent being therefore 32. There is another compound, the peroxide of sodium, which is formed when the metal is burnt in oxygen gas : it contains one-half more oxygen than soda, or it is a compound of one equivalent of sodium, 24, and one equivalent and a half of oxygen, 12, or its atomic weight is 36. To avoid the supposition of half an atom, this peroxide is regarded by some as a compound of two atoms of sodium and three of oxygen,



which will make its equivalent 72. Peroxide of sodium is of a yellowish or greenish colour, fusible, and loses its excess of oxygen by the action of water. The existence of an oxide at a lower degree of oxidation was stated by Gay-Lussac: it is of a greyish colour, dull and brittle; it is supposed to be a mixture of soda and sodium.

From its strong attraction to oxygen, sodium decomposes water rapidly, soda being formed by its oxygenation, and hydrogen disengaged; and if the water is in small quantity, the heat produced is such as to inflame the sodium. It is inflamed by nitric acid, and is rapidly oxidated by the other acids. It attracts oxygen from metallic oxides, and acts on ammonia like potassium.

Sodium combines at a high temperature with hydrogen gas, the gas burning when it escapes into the air. It unites with sulphur and phosphorus, the combination being attended with the evolution of much heat and light, and the compounds being similar in external properties to those formed by potassium with the same inflammables. Sodium burns in chlorine gas, and a compound results, which, when dissolved in water, becomes muriate of soda, the most important saline substance with which we are acquainted. Conversely, when muriate of soda is dried and heated, it becomes chloride of sodium. As its chemical properties are exhibited only when it is in the state of muriate, its history will be given with more propriety among the salts of soda. The same remark applies to the iodide of sodium, which is the same with the dried hydriodate of soda.

Sodium unites with the metals, forming compounds which retain the metallic properties. When combined with quicksilver in so small a proportion as  $\frac{1}{40}$ , it renders it fixed, forming a solid which has the appearance of silver. All these compounds are decomposed by exposure



to air or water, the sodium by absorption of oxygen being converted into soda.

SODA is usually obtained from the combustion of marine vegetables, of which different species afford it in different quantities and states of purity. The various kinds of fuci or sea-weed afford in this country the impure alkaline product, known by the name of Kelp; on the shores of the Mediterranean, the *salsola*, *salicornia*, and others, afford the purer Barilla. Even it contains much foreign matter: the soda is combined with the carbonic acid, and with this are associated muriate and sulphate of soda, a small portion of hydriodate of potash or soda, charcoal, lime, magnesia, silica and alumina. The origin of the soda afforded by the process is not altogether determined, but it is most probable that it is ultimately derived from the muriate of soda with which these plants are from their situation supplied; as when they are transplanted to an inland situation, it is established by the experiments of Du Hamel and Cadet, that the quantity they afford diminishes progressively, and after some years they afford only potash. Vauquelin's experiments prove, that in the *salsola soda*, carbonate as well as muriate of soda exists previous to the combustion.

It is usually from barilla that soda is procured. The barilla in powder being lixiviated with boiling water, the solution on evaporation affords crystals of carbonate of soda. To remove the acid, the same process is employed as in procuring potash. The salt is dissolved in twice its weight of water, and filtered through slaked lime. The lime abstracts the carbonic acid, its affinity to it being aided by the large quantity of it used, and the slowness with which the solution passes through it. Still the soda has a small quantity of carbonic acid combined with it: to obtain it pure, therefore, it requires, like potash, to



be submitted to the action of alcohol, though the product scarcely succeeds so well. Soda thus obtained is in the state of a solid white mass: it is crystallized with difficulty in irregular prisms: even in its driest state it contains, like potash, a portion of combined water, which cannot be expelled by heat; or it is a hydrate consisting of one atom of soda, 32, and one of water, 9. This water modifies its properties, the alkali obtained by the oxidation of sodium being harder, heavier, and less fusible than the hydrate. The latter melts at a red heat, and at a higher heat is volatilized.

Soda has all the alkaline properties equally with potash. It is acrid and caustic, and abundantly soluble in water. It changes the vegetable colours to a green, is powerful in neutralizing the acids, and with oils it forms soap. It is acted on by sulphur and phosphorus, sulphurets and phosphurets of sodium being partially or entirely the products. When these are thrown into water, they decompose it: when sulphur has been combined with the sodium, sulphuretted hydro-sulphuret of soda is formed. Soda does not act so energetically on the metals as potash, nor on the earths. It combines with the latter, however, by fusion, and forms with them, especially with silica, a very perfect glass. Soda combines with all the acids, exceeding potash in power of neutralization. Its salts are soluble and crystallizable. They are chiefly distinguished by the forms of their crystals. From the salts of potash, to which they bear the greatest resemblance, they are discriminated by not yielding crystals of alum when added to a solution of sulphate of alumina, and not throwing down a precipitate from muriate of platina.

Soda forms with sulphuretted hydrogen a saline compound of a white colour, crystallized in tetrahedral prisms acuminate by four planes: its taste is extremely bitter:



it dissolves abundantly in water : its solution is colourless, but gives a green tinge to paper : it has a smell of sulphuretted hydrogen. Acids produce with it a brisk effervescence, and render this odour very strong ; but they do not render the liquid turbid. Nitrous acid and chlorine, however, produce a precipitate of sulphur.

**CARBONATE OF SODA.** This salt is extracted from *barilla* by lixiviating it with warm water, and evaporating the solution, so that in cooling it shall crystallize : the salt is alkaline, its taste is acrid, and it changes the vegetable colours to a green. The crystals are octohedrons ; they are efflorescent ; they require twice their weight of water at  $60^{\circ}$  for solution. Exposed to heat, they suffer the watery fusion from the action of the water of crystallization they contain : as this is dissipated, the salt appears as a dry white powder, which by an increase of heat may be fused. The real salt, it is inferred, consists of one atom of acid, and one of soda ; but it always contains a large quantity of water, calculated even to amount in general to 10 atoms.

**BI-CARBONATE OF SODA** may be obtained, by transmitting carbonic acid gas through a solution of the carbonate : by evaporation it is then obtained in crystals. Containing twice as much carbonic acid as the other, Dr Wollaston gave it its present name. The anhydrous salt consists of two atoms of carbonic acid and one of soda, and contains, in general, also, according to Dr Thomson, an atom of water. The native carbonate of soda, found in Africa, and called *Trôna*, consists, according to Mr R. Phillips, of one equivalent of soda, and one and a half of carbonic acid, or it is a sesqui-carbonate of soda.

**NITRATE OF SODA** crystallizes in prisms. Its taste is cool ; it slightly attracts moisture from the air ; is soluble in 3 parts of water at  $60^{\circ}$ , and in an equal weight of boil-



ing water; like the nitrate of potash, it excites deflagration with inflammable bases: according to Prout, indeed, fire-works may be made with it more economically than with nitre.

**SULPHATE OF SODA.**—This is the salt known by the name of Glauber's Salt, from Glauber the chemist, by whom its properties were first noticed. He obtained it from the residuum of the distillation of muriatic acid from muriate of soda and sulphuric acid: this consists of the soda of the muriate of soda, with sulphuric acid in excess: it is dissolved in water: the excess of acid is neutralized by adding lime; the fluid is allowed to remain until it becomes clear, is drawn off in shallow leaden vessels, and on cooling affords the neutral sulphate in crystals. It is also obtained as a residuum in the preparation of sal-ammoniac from muriate of soda and sulphate of ammonia. It crystallizes in six-sided prisms bevelled at the extremities: its taste is strongly saline and bitter: it is efflorescent, the crystals in a dry atmosphere soon becoming white and opaque, and at length they fall into powder: it is soluble in three times its weight of water at  $60^{\circ}$ , and in less than its own weight at  $212^{\circ}$ . Exposed to heat it undergoes the watery fusion, losing *56 per cent.* of water. Like sulphate of potash it can combine with an excess of acid, forming Bi-sulphate of Soda, which is more soluble than the neutral salt.

**SULPHITE OF SODA** is in white and transparent prismatic crystals, soluble in four parts of water. **HYP0-SULPHITE OF SODA** may be formed in the same way as the hypo-sulphite of potash. It crystallizes on evaporation: it has a bitter taste, and exposed to the air it deliquesces. When heated it undergoes the watery fusion; if it be heated when dry, it takes fire and burns with a bright flame.

**PHOSPHATE OF SODA**, a salt employed in medicine, is



prepared by adding to the acidulous phosphate of lime, obtained from burnt bones, (vol. i. p. 636,) a solution of carbonate of soda, to saturate the phosphoric acid; phosphate of lime is precipitated, and the water holding dissolved the phosphate of soda is separated by filtration; by evaporation the salt is obtained crystallized in rhomboidal prisms. They effloresce on exposure to the air, are soluble in 3 parts of cold water, and in  $1\frac{1}{2}$  parts of boiling water. The taste of this salt being purely saline, without bitterness, it has been introduced into the practice of medicine as a substitute for other aperient salts. As it melts easily, and promotes the fusion of the earths and metallic oxides, it is used as a flux, in analyses performed by the blow-pipe. PHOSPHITE OF SODA is soluble and crystallizable. Before the blowpipe it decrepitates, emitting a phosphorescent light. HYPO-PHOSPHITE OF SODA is extremely soluble in water, and also in alcohol.

BORATE, or rather BI-BORATE OF SODA, the Borax of commerce, is a native production, being obtained from a lake in Thibet, from the sides of which it is dug up, and where there appears to be a constant reproduction of it. In the state in which it is imported, it is impure, but is purified by calcination, solution and crystallization. In the state in which it is met with in the shops, it is in the form of crystalline masses, of a figure approaching to an hexaedral prism. It is not perfectly neutral, the alkaline quality predominating even over the excess of acid: it is soluble in 12 parts of cold, and in six parts of boiling water: when exposed to a moderate heat, it melts from the water of crystallization it contains: when this is evaporated, there remains a spongy white mass, named Calcined Borax. If the heat be raised to ignition, this is melted into a pellucid glass. Borax is decomposed by the greater



number of the acids and by potash and the earths, the former uniting with its alkali, the latter with its acid. From the facility with which it melts and brings other substances into fusion, it is of use in some arts; as in making of glass, especially the finer glass for imitating the gems; in assaying minerals by the blowpipe; and in soldering the more valuable metals.

MURIATE OF SODA, or, when perfectly dry, Chloride of Sodium, is the salt which exists in largest quantity in nature. It is the principal saline ingredient of the water of the ocean, forming what is named Sea Salt, and it exists in immense beds in the earth, forming Rock Salt. In the latter, it is nearly pure: in the former it is less so, a portion of other salts adhering to it, greater or less according to the method in which it is procured. In warm climates, it is obtained by spontaneous evaporation, the sea-water being admitted into shallow trenches by the sea-side, and spread over an extensive surface: as it becomes concentrated by the evaporation, the liquor is removed, by sluices, from one trench to another, until at length the salt crystallizes spontaneously, and nearly pure. In colder climates, the sea-water is evaporated in large boilers by the application of heat, and the evaporation is carried so far, that the salt concretes in small crystals on the surface of the boiling liquor. As obtained by this mode, small portions of muriate and sulphate of magnesia adhere to it, which render it slightly deliquescent, and somewhat impair its antiseptic power. Muriate of Soda or Chloride of Sodium crystallizes by slow evaporation in cubes; it has a saline taste with scarcely any bitterness; is soluble in three parts of cold water, and its solubility is very little increased even at  $212^{\circ}$ ; hence it crystallizes from its solution, not by cooling, but by slow evaporation. Its crystals neither deliquesce nor effloresce; they decre-



pitrate when suddenly exposed to heat, the water of crystallization being dissipated in vapour; the salt melts at a red heat, and at a more intense heat is volatilized. When perfectly dry, it consists of one atom of chlorine 36, and one of sodium 24, = 60.

Muriate of Soda, or Chloride of Sodium, is in common use to counteract the process of putrefaction in animal matter, and the theory of its antiseptic operation is not well understood: it is taken universally as a condiment to food, and it is employed in a number of chemical arts. The decomposition of it, so as to obtain its alkaline base, is a process of much importance, as affording a source whence soda can be abundantly procured. It has been attempted on the large scale by the intermedium of oxide of lead, of carbonate of potash, of lime and iron; but the process by which it is at present effected, is to decompose it first by sulphuric acid, obtaining muriatic acid, and then to expose this sulphate of soda, mixed with charcoal, and lime or chalk, to a violent heat for some hours. The sulphuric acid loses part of its oxygen, which passing to the charcoal, forms carbonic acid; this unites with the soda, and the carbonate of soda is extracted from the mass by solution. Much of the carbonate of soda used by soap-makers and bleachers is now prepared in this manner. CHLORATE OF SODA is not so easily obtained pure as that of potash, as it is nearly of the same degree of solubility with muriate of soda, and is therefore not easily separated from it by crystallization. It crystallizes in cubes, is deliquescent, and is soluble in 3 parts of water.

FLUATE OF SODA is less sapid than fluuate of potash, is neither deliquescent nor efflorescent, and can be obtained in minute crystals.

HYDRIODATE OF SODA is soluble and crystallizable in large flat rhomboidal prisms; by heat it is converted into



iodide of sodium. Iodate of Soda crystallizes in minute prisms or grains of a cubic form, which are not altered on exposure to the air; they deflagrate on burning fuel.

The resemblance in properties between soda and potash is so great, that the distinctions between them require rather minute attention to discover them. Soda appears to have a less strong attraction to water: in their combinations they can be at once distinguished, the salts formed by the one united with the acids, having qualities altogether different from those of the other. Both are applied to the same purposes. The following tables exhibit the composition and atomic weights of the more important compounds of Sodium and of Soda, in reference to hydrogen as unity.

## COMPOUNDS OF SODIUM.

	Sodium. 1 atom = 24.	Weight of the other body.	Atomic weight of the com- pound.
Chloride, .....	24	36	60
Iodide, .....	24	124	148
Oxide, (soda,) .....	24	8	32
Peroxide, .....	24	12	36
Phosphuret, .....	24	12	36
Sulphuret, .....	24	16	40

## SALTS OF SODA.

	Soda. 1 atom = 32.	Acid.	Water. 1 atom = 9	Atomic weight of the salt.
Acetate, .....	32	50		82
Cryst. 6 water, .....	32	50	54	136
Arseniate, .....	32	62		94
Cryst. 8 water, .....	32	62	72	166
Binarseniate, .....	32	124		156
Cryst. 5 water, .....	32	124	45	201
Arsenite ? .....	32	54		86
Benzoate, .....	32	120		152
Bi-borate, (borax,) 8 water, .....	32	48(2 at.)	72	152
Carbonate, (sub-carbonate,) .....	32	22		54
Cryst. 10 water, .....	32	22	90	144
Bicarbonate, .....	32	44		76
Cryst. 1 water, .....	32	44	9	85



	Soda.	Acid.	Water.	Atomic weight of the salt.
Sesquicarbonate, cryst. 2 water, .....	32	33	18	83
Chlorate, .....	32	76		108
Chromate, .....	32	52		84
Cryst. 12 water, .....	32	52	108	192
Citrate, .....	32	58		90
Hydriodate, .....	32	125		157
Iodate, .....	32	164		196
Molybdate, .....	32	72		104
Nitrate, .....	32	54		86
Oxalate, .....	32	36		68
Bincoxalate, .....	32	72		104
Cryst. 3 water, .....	32	72	27	131
Phosphate, .....	32	28		60
Cryst. 12 water, .....	32	28	108	168
Sacclactate, 5 water, .....	32	104	45	181
Succinate, .....	32	50		82
6 water, .....	32	50	54	136
Sulphate, .....	32	40		72
Cryst. 10 water, .....	32	40	90	162
Bisulphate, .....	32	80		112
Sulphite, .....	32	32		64
Tartrate, .....	32	66		98
Tungstate, .....	32	150		182
6 water, .....	32	150	54	236
Urate, 1 water, .....	32	72	9	113

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## CHAP. IV.

### OF LITHINA.

THIS new alkali was discovered in 1818 by Arfwedson, a Swedish chemist associated with Berzelius, in a rare mineral named Petalite. It has been since found in the mineral named Spodumene or Triphane; also in lepidolite, and some varieties of mica; and in some mineral waters, as that of Carlsbad. In petalite, it exists in the quantity of 5 *per cent.* along with alumina and silica in spodumene, the proportion is about 8 *per cent.* It has been named Lithina, from its occurring in the mineral



kingdom ; and its metallic base, which has been obtained by Sir H. Davy, is denominated Lithium.

Lithina is extracted from these minerals by calcining them with nitrate or carbonate of barytes, then adding muriatic acid, which dissolves the barytes and alumina, and the lithina, leaving the silica. From this solution the barytes is precipitated by sulphuric acid, and the alumina by carbonate of ammonia ; by evaporation, exposure to heat, and solution, sulphate of lithina is obtained nearly pure. Acetate of barytes precipitates the sulphuric acid, and acetate of lithina is obtained, which, by heat, is converted into carbonate. An easier process is recommended by Berzelius, that of mixing spodumene or petalite in powder with twice its weight of fluor spar, and heating with sulphuric acid : the fluoric acid disengaged dissolves the silex, and escapes in the gaseous form ; and there remains only sulphates of lithina and alumina : by boiling with solution of ammonia, filtering, evaporating to dryness, and exposing to a red heat, pure sulphate of lithina is obtained, which may be converted into the carbonate. The alkali may be obtained pure by abstracting this acid.

Lithina thus obtained is of a white colour : exposed to the air it absorbs carbonic acid, and becomes a carbonate. Its taste is caustic, and it changes the vegetable colours to a green. It is less soluble in water than potash or soda, and it is scarcely soluble in alcohol. From its low combining weight, its capacity of saturation, in relation to the acids, is superior to that of the other alkalis, a circumstance which first led to its discovery. It consists, according to Dr Thomson, of one atom of lithium, 10, and one of oxygen, 8 ; hence its equivalent is 18.

The greater number of its salts are very soluble in water, and also very fusible. The Carbonate melts at a red heat : when heated in a platina crucible, it acts strongly



on the metal : it is not very soluble in water, but it gives a taste similar to that of the other alkalis. The Nitrate crystallizes in four-sided prisms, and is very deliquescent. The Sulphate crystallizes readily, and the crystals contain no water of crystallization ; it is fused by a heat inferior to redness. The Chloride of Lithium, when dry, or Muriate of Lithina, when moist, is also deliquescent, and like the former liquefies at a temperature much below a red heat. Lithina combines with sulphur, forming a yellow coloured sulphuret very soluble in water.

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## BOOK V.

### OF EARTHS AND THEIR BASES.

THE earthy aggregates which occur in nature are usually heterogeneous or compound ; but by analysing them, chemists have arrived at the knowledge of a few substances, of no lustre or transparency, having a loose texture, insoluble in water, or sparingly soluble, unflammable, difficultly fusible, and of moderate specific gravity. These resisting farther analysis, they regarded as simple substances, distinguishing them by the name of Earths. Four substances of this kind were known to the older chemists, silex, alumina, magnesia, and lime : barytes and strontites were afterwards made known ; and more lately, zircon, glucine, and yttria have been added to the number.

The important discovery was made by Sir H. Davy, that the Earths are not simple substances, but compounds of oxygen with bases somewhat similar to those of the alkalis, potassium and sodium. From the similarity of the



earths to metallic oxides, they had often been supposed to be of a metallic nature, and their reduction had frequently been attempted, and at one time had even been supposed to have been accomplished. This, however, was a mistaken result; and nothing was known with regard to their composition, until Davy, after his discovery of the chemical constitution of the alkalis, submitted the earths to the action of galvanism. Though results were obtained indicating their composition, they were less perfect than those obtained with regard to the alkalis, owing partly to the strength of affinity between the principles of the earths, partly to their being less perfect electrical conductors. By submitting them to the galvanic action in mixture with potash, or with metallic oxides, results more distinct were obtained: and a method employed by Berzelius and Pontin proved still more successful,—placing them in the galvanic circuit with quicksilver. They thus obtained the metallic bases of barytes and lime in combination with the quicksilver. Sir H. Davy, by the same method, decomposed strontites and magnesia. By submitting silex, alumina, zircon, and glucine, to the action of the galvanic battery in fusion with potash or soda, or in contact with iron, or by fusing them with potassium and iron, appearances were obtained indicating their decomposition, and the production of bases of a metallic nature; and there can thus remain little doubt, that all the earths are compounds, and of similar constitution.

The metallic bases of the earths approach more nearly than those of the alkalis to the common metals, and the earths themselves have a stricter resemblance than the alkalis to metallic oxides. Yet there are also grounds for retaining their distinction as a natural order, forming the link which connects the alkalis with the metals.

Of the characters assigned to the earths, none can be



regarded as altogether distinctive. They are usually said to be insipid; but there are three of them, barytes, strontites, and lime, which have a strong taste: they have also been considered as insoluble in water; but these earths are soluble to a certain extent. Infusibility is a character less equivocal, as there is none of them but what requires a very intense heat for its fusion. They are altogether unflammable, a property obviously arising from their being substances saturated with oxygen. Barytes, however, absorbs oxygen at a high temperature, a property in which it resembles the fixed alkalis. In common with metallic oxides, they are destitute of metallic lustre and opacity.

The earths like the alkalis combine with the acids, forming salts, which, in the due proportions, are neutral. There is an exception to this in one earth, silex, which, in the humid way, scarcely unites with any acid but the fluoric, and with it does not produce the state of neutralization. It is the substance, therefore, which is at once most remote from the alkalis, and from the metallic oxides; and, indeed, by some chemists, it has been regarded as more analogous to an acid.

One property has been assigned as distinctive of the earthy from the metallic salts, that the solutions of the former are not precipitated by the triple prussiate of potash, or ferrocyanate of potash as it is frequently called. This is not, however, without exceptions; the earth named Yttria, and also, as Klaproth has affirmed, zircon, giving precipitates with this test. In general, the earthy salts are not much altered by infusion of galls, a re-agent which so sensibly affects metallic salts: they are generally of a white colour. Yttria affords also, however, an exception to these, some of its salts having a red colour, and being precipitated by infusion of galls: this colour, however, is said to depend on impurity.



Several of the earths combine, like the alkalis, with chlorine and iodine; and those which have alkaline properties, as lime, have these neutralized by the union. These compounds have little permanency; the chlorine and iodine, if water is present, passing to the state of muriatic and hydriodic acids.

It has been generally supposed, that the earths combine with sulphur and phosphorus, in the same manner as the alkalis were believed to unite with these inflammables. The experiments of Vauquelin, Berthier, and Berzelius, however, which have been already stated, throw much doubt on this opinion, and render it more probable that the sulphur and phosphorus combine directly with the metallic bases of the earths, expelling the oxygen, and that thus metallic sulphurets and phosphurets are formed. Gay-Lussac, however, is of opinion, that if sulphur is fused with the earths, and the temperature not raised to any great extent, sulphurets of the earth are formed. By fusion with either of the fixed alkalis, the earths form glasses; and the alkali, digested with water on several earths, dissolves a portion of them. The earths also combine with the metallic oxides by fusion, forming coloured glasses.

Lastly, the earths exert affinities to each other. Several of them combine by fusion, forming glasses more or less transparent. And when two earths are boiled together in water, it frequently happens that one of them, which may be insoluble by itself, is dissolved by the affinity exerted to it by the other earth, which is itself of sparing solubility. The earths combine with the alkalis, either by heat, or in the humid way.

Of the different earths, barytes, strontites, and lime, have properties considerably analogous to those of the alkalis. They are to a certain extent soluble in water; their



solution has an acrid taste, and changes the vegetable blue and purple colours to a green. They have hence been named Alkaline Earths, and may be placed at the head of the order, forming the transition from the alkalis.

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## CHAP. I.

### *id by some Baryta* OF BARYTES AND ITS BASE, BARIUM.

THIS earth was discovered by the Swedish chemists Scheele and Gahn. It received the name of Terra Ponderosa, from the great weight of its combinations, a name changed by Kirwan to Barytes, from (*βαρὺς, heavy.*) It occurs in nature combined with sulphuric and carbonic acids.

Barytes had always been supposed to be of a metallic nature, partly from the great weight of its native combinations, and partly from some of its salts proving poisonous to animals. Sir H. Davy, on placing it slightly moistened, in the galvanic circuit, obtained appearances of decomposition, and the evolution of metallic matter. The method discovered by Berzelius and Pontin, of placing the barytes in contact with quicksilver, succeeded more completely: a portion of native carbonate of barytes was made into a paste with water, and a globule of quicksilver placed in a hollow on its surface; the paste was placed on platina connected with the positive pole of a battery, and the quicksilver touched with the negative wire. The fluidity of the quicksilver soon diminished, and an amalgam was obtained, from which the quicksilver was separated by distillation, leaving the metallic base of the barytes. This substance, which Sir H. Davy named BA-



RIUM, is possessed of the following properties. It is solid, of a white colour, with metallic lustre, having a resemblance to silver. It melts at a heat inferior to ignition, but is not volatilized even when heated to redness. Exposed to the air, it tarnishes rapidly, from absorbing oxygen, and falls into a white powder, which is barytes. Dropt into water, it immediately decomposes it, evolving hydrogen, and being converted into barytes. It sinks not only in water, but in sulphuric acid; and Davy supposed it to be four or five times heavier than water. It is flattened by pressure strongly applied. Barium, it has been stated by Dr Clarke, may be obtained by exposing barytes mixed with oil to a kindled stream of oxygen and hydrogen. The combining weight of Barium has been determined to be 70: united with one equivalent of oxygen, 8, it forms barytes, the combining weight of which is therefore 78.

An oxide of barium may be formed, containing an additional atom of oxygen, by heating barytes to a low red heat, exposed to the air, or to oxygen gas; oxygen is absorbed, and the barytes vitrifies at the surface, and becomes of a greyish colour; this is the deutoxide or peroxide of barium: it was employed by Thenard, as has been stated, in the formation of oxygenated water.

Sulphuret of barium, procured by the methods of Berthier and Berzelius, is described as a light grey coloured mass, composed of crystalline grains loosely aggregated. When thrown into water it was completely dissolved forming a clear and colourless solution, being converted, it is inferred, into a hydro-sulphuret of barytes, the barium attracting oxygen from the water, and the sulphur uniting with the evolved hydrogen: accordingly, the addition of muriatic acid disengaged sulphuretted hydrogen. When heated with three or four times its weight of nitre, the



sulphuret was completely re-converted into sulphate of barytes. This sulphuret consists of one atom of barium, 70, and one atom of sulphur, 16, = 86.

Chloride of barium is merely the dried muriate of barytes; it may be formed also by passing chlorine gas over barytes at a red heat, oxygen gas is evolved, and chloride of barium formed. Iodide of barytes, in like manner, is the dried hydriodate of barytes. ~~barium~~

BARYTES is procured either from the native carbonate or sulphate. From the former it may be obtained by a method pointed out by Dr Hope: this consists in exposing the carbonate in a black lead crucible to the intense heat of a forge fire; the carbonic acid is expelled, and by dissolving the residual matter in water, the pure barytes may be crystallized. The sulphate of barytes may be decomposed, by exposing it to a red heat for two hours in a covered crucible, mixed with one-third its weight of charcoal. By adding water to the residual matter, a compound of barytes with sulphur and sulphuretted hydrogen is dissolved; from this the barytes may be precipitated in the state of carbonate, by the addition of carbonate of potash; or by adding nitric acid, nitrate of barytes is formed, and can be obtained crystallized; and either the carbonate or nitrate thus procured can be decomposed by exposure to heat, and the pure earth obtained. Barytes obtained from the decomposition of the nitrate by heat, appears to be free, or nearly so, from combined water. It is then in the form of a grey solid mass, having a harsh and caustic taste, and a specific gravity of 4: on exposure to the air, it slakes and falls to powder like lime, gaining weight from the absorption of water; a similar change with the production of much heat, and, according to Döbereiner, even of light also, is produced by the affusion of water. When a sufficient quantity of water is



added, the hydrate dissolves, and afterwards consolidates, in transparent needle-like crystals, as the solution cools. This hydrate appears to consist of one atom of barytes, 78, and one of water, 9, =87. The crystallized hydrate contains, according to Mr Dalton, not less than 20 atoms of water, or 180 parts to 78 of dry barytes. The fusibility of this earth has been variously stated, according as it is combined or not with water. The crystals readily suffer the aqueous fusion; as the water is dissipated, a dry powder remains, which, by an increase of heat, may be melted into a glass. The fusibility of this, however, is still owing to the presence of a portion of water; when the real barytes obtained from the decomposition of the nitrate is submitted to experiment, the most intense heat is necessary to produce fusion.

Barytes is soluble in water. The crystallized barytes is soluble in 17.5 of water at 60°: in a drier state it requires about 25 parts; boiling water dissolves one-half its weight, and the solution affords crystals on cooling.—The crystals are described by Dr Hope, who observed the crystallization of this earth, as flat six-sided prisms acuminated by four planes: they lose their water on exposure to the air, and from the application of heat. The watery solution has a strong acrid alkaline taste, and changes the vegetable blue colours to a green; it has thus distinct alkaline properties; a film forms on it when exposed to the air, from absorption of carbonic acid.

Barytes unites with several of the earths by fusion, and also in the humid way, and communicates to them solubility, or otherwise modifies their properties. Thus it renders argil soluble in water, and silex it enables to combine with different acids.

Barytes combines with the acids; and as it decomposes a number of the salts which the alkalis form with the



acids, it has been supposed to exert to them stronger attractions. These decompositions, however, may partly perhaps be ascribed to the exertion of the force of cohesion, since the compounds which it forms with these acids are extremely insoluble, as much as to its superior strength of affinity. The barytic salts are in general of very sparing solubility. Some of them, however, as the nitrate and muriate, are soluble. They are easily known by the copious precipitate they afford on the addition of sulphuric acid or its compounds. Their taste is usually acrid; they are poisonous, and communicate a yellow tinge to the flame of alcohol.

CARBONATE OF BARYTES exists native, forming the mineral called Witherite. It may be formed by adding carbonic acid to barytic water, or by decomposing muriate of barytes by an alkaline carbonate: it is then a white powder, of considerable specific gravity, insoluble in water, but dissolved in small quantity, when the water is impregnated with carbonic acid. The native carbonate, and the artificial carbonate after it has been ignited, consist of one atom of acid, 22, and one of barytes, 78, = 100. The artificial carbonate is decomposed by heat, its carbonic acid being expelled; while in the natural carbonate, which contains less water, the decomposition is more difficult; this difference is owing to the water contained in the artificial carbonate, which, by the affinity it exerts to the barytes, favours the separation of the carbonic acid. When the native carbonate is exposed to a red heat, mixed with charcoal, it is decomposed, its carbonic acid being converted into carbonic oxide.

NITRATE OF BARYTES is obtained by dissolving the native carbonate in diluted nitric acid; it crystallizes on evaporation, in octohedrons, or in small brilliant plates: they are soluble in 10 or 12 parts of water at 60°, and in



3 or 4 parts of boiling water. It is decomposed by heat, its acid being converted into oxygen and nitrogen gases. It detonates but feebly, with inflammable bodies.

**HYDRO-SULPHURET OF BARYTES** is formed when sulphuret of barium is thrown into water; it is formed also by transmitting sulphuretted hydrogen through a solution of barytes, or by boiling barytes and sulphur together in water; it is abundantly soluble, crystallizes in white six-sided prisms, having a silky lustre; an acid expels sulphuretted hydrogen from them.

**SULPHATE OF BARYTES** is formed when barytes is presented to sulphuric acid, in whatever state of combination either may previously exist. It is precipitated in a white powder, which is not soluble in water in any appreciable quantity, requiring, it is calculated, above 43,000 times its weight of water, either hot or cold, for its solution. It is from this circumstance, that solution of barytes is an excellent test for ascertaining the presence of sulphuric acid, a very minute quantity of which may be at once detected in any liquid, by adding either this solution of the pure earth, or of some of its soluble salts. Sulphate of barytes is melted by a strong heat. When heated with carbonaceous matter its acid is decomposed; and if the heat is strong and continued, sulphuret of barium is formed. The determination of the proportions of its constituent parts is of considerable importance, as it is usually employed as the mode of obtaining sulphuric acid free from water, in experiments made to estimate its quantity. They are now fixed with precision at 66.1 of dry barytes, and 33.9 of dry or real acid in 100 parts; or the compound consists of one atom of sulphuric acid, 40, and one of barytes, 78. Sulphate of barytes may be partially decomposed, by boiling it for a considerable time in a solution of carbonate of ammonia or of potash: after two



hours' boiling, about a fourth of it is converted into carbonate of barytes, and a sulphate of the alkali. This has been recommended as an easy method of procuring the carbonate, for obtaining from it the pure earth. Besides this neutral salt, barytes can combine with an excess of sulphuric acid in various proportions: it forms a liquid that congeals into a congeries of prisms; this is decomposed, and the neutral sulphate is precipitated, on the affusion of water.—SULPHITE OF BARYTES is insoluble, and has a taste slightly sulphureous.—HYPO-SULPHITE OF BARYTES. This salt is obtained by pouring muriate of barytes into a solution of hypo-sulphite of lime. According to Mr Herschell, it is a bin-hyposulphite. It is but sparingly soluble in water.—HYPO-SULPHATE OF BARYTES is soluble and crystallizable.

PHOSPHATE OF BARYTES is an insipid white powder, of considerable specific gravity: it is insoluble in water; is fusible at a high temperature; and is not decomposed by exposure to heat mixed with carbonaceous matter. Berzelius found, that when this salt is digested in phosphoric acid, a salt was formed which contains just twice the quantity of acid in the neutral phosphate; it is therefore a *Bi-phosphate of Barytes*. It has a taste slightly acid, and reddens litmus. When this salt in solution is poured into alcohol, a precipitate falls down, which Berzelius finds to contain  $1\frac{1}{2}$  as much acid as the neutral phosphate. It is then a *Sesqui-phosphate of Barytes*.—PHOSPHITE OF BARYTES is little soluble in water: it melts before the blow-pipe, emitting a phosphorescent light. HYPO-PHOSPHITE OF BARYTES is formed, when phosphuret of barytes is dropt into water. It remains in solution, while the phosphate is precipitated. It is very soluble, so that it can scarcely be crystallized.—BORATE OF BARYTES is a white powder, insipid, and insoluble.



MURIATE OF BARYTES is formed by submitting carbonate of barytes to the action of diluted muriatic acid. It is soluble in three parts of cold water, and in a smaller quantity of hot water; it crystallizes from the latter solution on cooling in quadrangular tables. It is also soluble in alcohol. When it is heated, it is conceived that the hydrogen of the muriatic acid, and the oxygen of the barytes unite to form water, which is dissipated by the heat; and there thus remains a chloride of barium. This, when dissolved in water, becomes again muriate of barytes. The solution of this salt, and that of nitrate of barytes are much used in analysing liquids, as mineral waters, which contain salts of sulphuric acid, the barytes forming with that acid an insoluble precipitate, while the muriatic or nitric acid neutralizes the base.

CHLORATE OF BARYTES is prepared by passing chlorine gas through a warm solution of barytes: chlorate and muriate of barytes are formed; the latter is removed by adding phosphate of silver, which throws down two precipitates, chloride of silver and muriate? of barytes: by ~~phosphat~~ evaporation the salt is obtained. It is soluble and crystallizable, its crystals being six-sided prisms: it yields oxygen when exposed to heat, and detonates with violence when heated with inflammable bodies.

FLUATE OF BARYTES is insoluble, but becomes soluble from an excess of acid.—HYDRIODATE OF BARYTES crystallizes in slender prisms, which are very soluble in water, though but feebly deliquescent. Heated under exposure to the air they are converted into iodide of barium. IODATE OF BARYTES is obtained by adding iodine to barytic water. It does not deflagrate like some other Iodates: by heat, however, it is decomposed.

The following Table exhibits the principal combinations of barium and barytes.



## COMPOUNDS OF BARIUM.

	Barium. 1 atom = 70.	Weight of the other body.	Atomic weight of the compound.
Chloride, .....	70	36	106
Iodide, .....	70	124	194
Oxide, (barytes,) .....	70	8	78
Peroxide, .....	70	16	86
Phosphuret, .....	70	12	82
Sulphuret, .....	70	16	86

## SALTS OF BARYTES.

	Barytes.	Acid.	Water.	Equivalent of the salt.
Acetate, .....	78	50		128
Cryst. 3 water, .....	78	50	27	155
Arsenate, .....	78	62		140
Arsenite ? .....	78	54		132
Borate, .....	78	24		102
Carbonate, .....	78	22		100
Chlorate, .....	78	76		154
Chromate, .....	78	52		130
Citrate, .....	78	58		136
Fluate, .....	78	10		88
Hydriodate, .....	78	125		203
Bin-hyposulphite, .....	78	48		126
Iodate, .....	78	164		242
Muriate, cryst. 1 water, .....	78	37	9	124
Nitrate, .....	78	54		132
Oxalate, .....	78	36		114
Cryst. 3 water, .....	78	36	27	141
Binoxalate, 3 water, .....	78	72	27	177
Phosphate, ... ..	78	28		106
Biphosphate, 2 water, .....	78	56	18	152
Sesqui-phosphate, .....	78	42		120
Phosphite, 1 water, .....	78	20	9	107
Succinate, .....	78	50		128
Sulphate, .....	78	40		118
Sulphite, .....	78	32		110
Tartrate, .....	78	66		144
Bitartrate, cryst. 2 water, .....	78	132	18	228



## CHAP. II.

*Ed by some Strontites*  
OF STRONTITES, AND ITS BASE STRONTIUM.

FOR the discovery of this earth we are indebted to Dr Hope. He obtained it from the native carbonate of strontites, found at the mine of Strontian in Argyllshire. This mineral had been considered as a variety of carbonate of barytes, until he shewed that the earth it contains is different from barytes and from any other: he at the same time pointed out its principal properties and chemical relations. Klaproth also and Pelletier afterwards proved the existence of this as a distinct earth. It derives its name from the place where it was first found. It has since been discovered native in different countries in the state of sulphate.

The decomposition of this earth has been effected by submitting it to the action of galvanism, in contact with quicksilver, in the same manner as barytes. To its base Sir H. Davy gave the name of STRONTIUM. Its properties have been only imperfectly examined. In lustre, colour, specific gravity, and other physical properties, it is similar to the metallic base of barytes; by exposure to the air, it is converted into strontites, absorbing oxygen and gaining weight in this conversion. Its combining weight is inferred to be 44.

STRONTITES is obtained from either the native carbonate or sulphate, by processes the same as those which have been described under the history of barytes. It is in the state of a dry solid mass, having a specific gravity between 3 and 4; it is composed of one atom of strontium,



44 and one of oxygen, 8, its equivalent is therefore 52. By dissolving it in boiling water, and allowing the solution to cool, crystals are formed, which are thin quadrangular tables, or compressed prisms, sometimes bevelled at the extremities ; they are transparent, but become white and opaque on exposure to the air ; exposed to heat they liquefy from the augmented solvent power of the water of crystallization ; when this is expelled, they lose two-thirds of their weight and become a hydrate, similar to what is produced by the affusion of water on the ignited earth obtained by the decomposition of the nitrate. This powder is not fused by a very intense heat.

Strontites is soluble in water, the crystals requiring 50 parts at 60° ; boiling water dissolves half its weight nearly. In its dry and uncrystallized state, it requires a much larger quantity, nearly 200 parts at 60°. The solution changes the vegetable colours to a green. This earth is likewise soluble in alcohol. It exerts no peculiar action on the alkalis, nor on the other earths.

Strontites combines with the acids forming salts, of which some are soluble and crystallizable ; others insoluble. The superiority in strength of affinity has been ascribed to this earth as to barytes, from its decomposing the salts of the alkalis and other earths ; but this probably arises partly from the same cause, the insolubility of the compounds it forms with the acids of the salts in which it occasions these decompositions. Its salts are in general decomposed by barytes. Dissolved in alcohol, they give it the property of burning with a blood red flame,—a property which is distinctive of this earth.

CARBONATE OF STRONTITES is precipitated, on adding carbonic acid, or a solution of an alkaline carbonate, to a solution of strontites, or of a strontitic salt. It requires 1536 parts of water for solution : with an excess of acid it becomes soluble.



NITRATE OF STRONTITES crystallizes in hexaedra prisms, or in octohedrons; it is soluble in its own weight of water at  $60^{\circ}$ , and at  $212^{\circ}$  in little more than half its weight. It is deliquescent in a humid, efflorescent in a dry atmosphere. It deflagrates feebly when laid on burning fuel.

HYDRO-SULPHURET OF STRONTITES is obtained by fusing sulphur with strontites, or by strongly heating the sulphate with charcoal, and dissolving the resulting sulphuret of strontium in water. A solution of a yellow colour is obtained, which contains hydro-sulphuret, and sulphuretted hydro-sulphuret of strontites: the former crystallizes in white prisms, having a silky lustre.

SULPHATE OF STRONTITES is in the form of a white powder, insipid, and so very sparingly soluble in water as to require nearly 4000 parts for its solution. Like barytes it also combines with an excess of acid, and is rendered more soluble in water and crystallizable. HYPO-SULPHITE OF STRONTITES may be obtained by passing a current of sulphurous acid through sulphuretted hydro-sulphuret of strontites: it crystallizes in transparent rhomboids, having a bitter taste, and soluble in 2 parts of boiling water; when heated, the dry salt burns with a weak flame. HYPO-SULPHATE OF STRONTITES crystallizes in small six-sided tables.

PHOSPHATE OF STRONTITES requires above 2000 parts of water for its solution. It melts into an enamel by the flame of the blow-pipe, giving a phosphorescent light. HYPO-PHOSPHITE OF STRONTITES is so soluble that it can with difficulty be crystallized. BORATE OF STRONTITES. This compound, formed by adding boracic acid to strontitic water, is described by Dr Hope as a white powder, soluble in 130 parts of boiling water, and changing vegetable colours to green.



MURIATE OF STRONTITES is so soluble as to require no more than its weight of water at  $60^{\circ}$  to dissolve it: in boiling water it is still more soluble, and it crystallizes from this solution on cooling, in slender six-sided prisms. By heat it is converted into a chloride of strontium.—CHLORATE OF STRONTITES is very soluble and deliquescent.—FLUATE OF STRONTITES is insoluble, but is rendered soluble by an excess of acid.—HYDRIODATE OF STRONTITES is very soluble, and is converted into an iodide of strontium when heated.—IODATE OF STRONTITES crystallizes in minute octohedrons, and when heated gives out water and is decomposed.

This earth resembles barytes in so many of its properties, that distinctive characters require to be pointed out by which they may be discriminated. Strontites itself is less soluble in water, while its salts, particularly the nitrate and muriate, are considerably more soluble in water; they are decomposed by barytes; and they give a blood-red colour to the flame of combustible bodies. Two re-agents distinguish them in their combinations. The watery solution of strontites is not like that of barytes precipitated by malic or gallic acid: and when the salts of strontites are decomposed by oxalic acid, the precipitate is not redissolved by an excess of acid, as that from the barytic salts is; nor, if the solutions are dilute, does the precipitate appear from the barytic salts, while it is sensible from those of strontites. Succinic acid and arsenious acid, it is farther stated, precipitate barytes, but not strontites.

The following Tables exhibit the constitution of the principal compounds of strontium and strontites:



## COMPOUNDS OF STRONTIUM.

	Strontium 1 atom = 44.	Weight of the other body.	Atomic weight of the com- pound.
Chloride, .....	44	36	80
Iodide, .....	44	124	168
Oxide, (strontites,) .....	44	8	52
Phosphuret, .....	44	12	56
Sulphuret, .....	44	16	60

## SALTS OF STRONTITES.

	Strontites 1 atom = 52.	Acid.	Water 1 atom = 9.	Equivalent of the Salt.
Acetate, .....	52	50		102
Cryst. 1 water, .....	52	50	9	111
Arseniate, .....	52	62		114
Cryst. 8 water, .....	52	62	72	186
Carbonate, .....	52	22		74
Chlorate, .....	52	76		128
Chromate, .....	52	52		104
Citrate, .....	52	58		110
Muriate, Cryst. 5 water, .....	52	37	45	134
Nitrate, .....	52	54		106
Oxalate, Cryst. 2 water, .....	52	36	18	106
Binoxalate, .....	52	72		124
Phosphate, .....	52	28		80
Cryst. 1 water, .....	52	28	9	89
Bi-phosphate, Cryst. 2 water, .....	52	56	18	126
Sulphate, .....	52	40		92
Tartrate, .....	52	66		118
Cryst. 3 water, .....	52	66	27	145

## CHAP. III.

## OF LIME.

THIS earth exists in great abundance in nature, usually in combination with acids. Its compound with carbonic acid forms the numerous varieties of marble, limestone,



chalk, and marl: with sulphuric acid it forms gypsum or plaster stone; and in these and other saline combinations it exists in the water of springs, in the water of the ocean, in vegetable and in animal matter.

Submitted to the action of galvanism in high intensity, lime in Sir H. Davy's experiments gave indications of decomposition; and by employing quicksilver, he obtained the amalgam of its base. This amalgam exposed to the air or to water absorbed oxygen, lime being reproduced. In an experiment designed to obtain the base in an insulated state by distilling the quicksilver from it, the tube broke while warm, and at the moment that the air entered, the metal, which had the colour and lustre of silver, took fire, and burnt with an intense white light into quicklime. To this base Davy gave the name of CALCIUM. Its atomic weight is inferred to be 20.

Lime is obtained with most facility from the native carbonate, from which, by a strong heat, the carbonic acid may be expelled. This process is conducted on a large scale with the different varieties of limestone, which are calcined or burnt, in order to obtain the caustic earth, or quicklime, as it is called. As this lime is not altogether pure, the chemist, to have it in a state of purity, dissolves marble or chalk in diluted muriatic acid, leaving an excess of lime undissolved; ammonia is added, which precipitates any argil or magnesia; the filtered solution is then decomposed by carbonate of potash, and the carbonate of lime being washed with water and dried, is decomposed by a strong heat.

Lime is white, moderately hard and brittle: its specific gravity is 2.3: it is composed of one atom of calcium, 20, and one of oxygen, 8; hence its equivalent is 28. Exposed to the air it quickly absorbs water, which causes it



to fall down into a white powder extremely fine; this is the slaking of lime. The same change takes place rapidly from the affusion of water; the quicklime absorbs one-fourth of its weight of the water, and becomes extremely hot from the water giving out its latent heat in passing to the state of a solid compound. According to Mr Dalton, the temperature rises to not less than  $800^{\circ}$ , and Pelletier has affirmed even that light also is emitted. This hydrate consists of one equivalent of lime, 28, and one of water, 9.

Lime is extremely infusible, melting only from the intense heat of galvanism, or of the oxy-hydrogen blowpipe. It is soluble in water; it presents the singularity, according to Mr Dalton, of being less soluble in hot than in cold water: water at  $60^{\circ}$  dissolving  $\frac{1}{778}$ th of lime, or  $\frac{1}{384}$ th of hydrate of lime; while at  $212^{\circ}$  it dissolves only  $\frac{1}{1276}$ th of the former, or  $\frac{1}{932}$ th of the latter: this remarkable fact has been ascertained also by Mr Phillips, who found that at  $32^{\circ}$  water dissolves fully  $\frac{1}{636}$ th of its weight of lime, or nearly twice as much as it does at  $212^{\circ}$ , and that when this solution was heated, lime was deposited. The solution, lime water as it is named, has a strong styptic taste, and changes the vegetable blue and purple colours to a green. Exposed to the air, a film forms on its surface from the absorption of carbonic acid, and the whole of the lime nearly is at length precipitated in the state of carbonate. The same absorption of carbonic acid takes place in dry lime, though much more slowly. By placing lime water in a vacuum with sulphuric acid, on Mr Leslie's principle, Gay-Lussac succeeded in obtaining crystals of hydrate of lime: they were small transparent hexahedrons.

Lime, it used to be supposed, combines with sulphur and with phosphorus; but it rather appears that its base alone, calcium, unites with these inflammables. The sulphuret of calcium is formed by heating sulphur with



lime in a covered crucible. It is of a reddish-yellow colour. When thrown into water, mutual decomposition takes place, and a sulphuretted hydro-sulphuret of a yellow colour, with a fetid odour, is produced. Phosphuret of calcium, or as it has been usually termed, phosphuret of lime, is obtained in the following manner: A few pieces of phosphorus are placed at the bottom of a glass tube, which is then filled with small pieces of lime; the part of the tube where the lime is, is heated red-hot, and the phosphorus is then sublimed by heat: its vapour passing over the lime decomposes it, and a reddish coloured phosphuret of calcium is formed. This substance is remarkable for decomposing water whenever it is dropt into it, causing an immediate production of phosphuretted hydrogen, which takes fire at the surface of the water; phosphite or hypo-phosphite of lime remains in solution.

Lime combines with the acids, neutralizing the acid properties. Its salts are in general decomposed by potash or soda, which precipitate the lime, but not by ammonia, probably from the tendency which this alkali has to form a ternary compound with the acid and the lime. Oxalic acid throws down lime from all the other acids; and this compound being quite insoluble, oxalic acid forms the most delicate test of the presence of lime.

CARBONATE OF LIME exists in nature in great abundance, and under a variety of forms, many of them regularly crystallized. It may be formed by adding carbonic acid to lime-water, or by decomposing any of the soluble salts of lime by any of the alkaline carbonates. It is very sparingly soluble in water; and in those forms of it in which the cohesion is considerable, as limestone and marble, appears to be altogether insoluble. Hence lime water is an excellent test of the presence of carbonic acid. By an excess of carbonic acid, carbonate of lime is rendered so-



luble. When exposed to heat, it first loses what water it contains, and, if transparent and hard, becomes white, opaque, and friable. If the heat be augmented, the carbonic acid is compelled, and pure lime remains. This operation is performed on a large scale, on the different varieties of the native carbonate, such as marble, chalk, and more particularly limestone, in order to obtain lime for the numerous uses to which it is applied. The experiments of Sir James Hall have proved, that if carbonate of lime be heated under strong pressure, so that the escape of its carbonic acid is prevented, it may be melted at a temperature even not higher than  $22^{\circ}$  of Wedgewood's scale: by this fusion it acquires considerable hardness and closeness of texture, approaching in these qualities, as well as in fracture and specific gravity, to the finer kinds of limestone or marble. Bucholz has since discovered, that even without compression, carbonate of lime may be fused by the sudden application of a violent heat, or by submitting it to heat in a large mass. The acids expel the carbonic acid with effervescence; and this property of effervescing strongly on the contact of an acid affords a discriminating character of carbonate of lime. The native carbonate, perfectly pure, consists of 56 of lime and 44 of acid.

NITRATE OF LIME is generally found in those situations in which nitrate of potash is formed, as in the mortar of old buildings. It can be obtained in slender prismatic crystals, deliquescent, and soluble in less than an equal weight of water at the temperature of  $60^{\circ}$ , and in still less boiling water. Exposed to heat, they undergo the watery fusion, and are decomposed, the acid being expelled. By having been heated it becomes phosphorescent, and retains this property when cold, forming Baldwin's solar phosphorus.



SULPHATE OF LIME, long known to chemists under the names of Gypsum and Selenite, is one of the saline substances most abundant in nature. It forms entire strata, is diffused in almost every soil, and is contained in almost all river and spring water, giving rise, when the quantity is considerable, to the quality of these named hardness. It requires about 500 times its weight of water at  $60^{\circ}$  for its solution. At that of  $212^{\circ}$  it is more soluble; and this latter solution, upon cooling slowly, deposits minute crystals. Exposed to heat, it appears to effervesce or boil, owing to the expulsion of its water; it becomes opaque and falls into a white powder. This, diffused in water, speedily consolidates from a species of irregular crystallization. HYDRO-SULPHURET OF LIME is formed by transmitting sulphuretted hydrogen gas through water in which lime is suspended. It is crystallizable and very soluble. The sulphuretted hydro-sulphuret of lime is formed when sulphuret of calcium is dissolved in water; from this property it is much used as a cement, forming plaster of Paris and stucco: it is used also in statuary under the name of Alabaster. SULPHITE OF LIME is soluble and crystallizable. HYPO-SULPHITE OF LIME is obtained by exposing a solution of sulphuret of lime to the air for some time. It may be obtained in prismatic crystals; these are soluble in an equal weight of water, but are insoluble in alcohol. It contains two atoms of acids, and hence might be more properly termed a bin-hyposulphite. HYPO-SULPHATE OF LIME crystallizes in six-sided tables.

PHOSPHATE OF LIME may be formed by decomposing the solution of an alkaline phosphate by muriate of lime; it is a white insoluble powder, which is imperfectly vitrified by a very intense heat. It exists in the mineral kingdom under different forms, and it constitutes 86 *per cent.* of the bones of animals. When partially decomposed by



an acid, it is converted into a bi-phosphate, which is soluble; and by evaporation of its solution, crystallizes in silky fibres, or in brilliant scales, which by heat are fused into a transparent glass. According to Mr Dalton's experiments, there exist not less than five phosphates of lime of definite composition, a phosphate, bi-phosphate, tri-phosphate, quadri-phosphate, and octo-phosphate of lime.

MURIATE OF LIME, or, in its dry state, CHLORIDE OF CALCIUM, is obtained by dissolving carbonate of lime in muriatic acid, or the chloride may be formed by heating lime in chlorine gas, when oxygen is evolved, and chloride of calcium produced. It is extremely soluble in water, the water taking up so much of it as to become of a thick consistence. By cooling its saturated solution, it may be obtained crystallized in six-sided prisms; these crystals are so deliquescent, that they are not easily obtained dry; they liquefy on exposure to the air, and they combine rapidly with ice or snow, causing it to melt, and thus producing intense cold. They contain an atom of acid, and one of base, and six of water. From its great attraction to moisture, fused chloride of calcium is frequently used in chemical experiments to deprive gases of any hygrometric vapour existing in them \*.

CHLORIDE OF LIME. It has been already stated, that chlorine forms compounds with the alkaline and earthy bases. This compound with lime is the best marked and most important of them. It is formed by passing chlorine gas over slaked lime; the chlorine is rapidly absorbed with an evolution of heat. This forms the bleaching powder,

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\* According to Dr Murray's view of the nature of Mineral Waters, to be afterwards stated, muriate of lime is their most common and generally their most active ingredient. It is a salt of considerable medicinal power, and has been found of much utility in several diseases, particularly in scrofula.



the properties of which have been already described. According to Mr Dalton, this compound in the dry state is strictly a sub-chloride of lime, or a dichloride, as it is termed by Dr Thomson, containing two atoms of lime to one of chlorine; it contains also six atoms of water. When dissolved in water, however, half of the lime is deposited, and a true chloride of lime remains in solution. On the new view of the nature of chlorine, it is, of course, not admitted to be a salt; yet it has all the characters of one; the alkaline properties of the lime are neutralized, and even in a great measure those of the chlorine, as it exerts little bleaching power, unless an acid is added to separate the chlorine. When the subchloride is kept for some time, it suffers decomposition, becoming muriate of lime.—CHLORATE OF LIME is very deliquescent, and is soluble in water and in alcohol.—FLUATE OF LIME is insoluble, but becomes soluble from an excess of acid. It is obtained in nature in a very different state, forming fluor-spar, often crystallized in large and regular cubes, transparent, of rich colours, vitreous lustre, hard and brittle.—HYDRIODATE OF LIME is very soluble and deliquescent: by heat it is converted into iodide of calcium.—IODATE OF LIME crystallizes in six-sided tables.

Of the different earths, lime is most extensively used. It is applied as a manure in agriculture; it forms the basis of mortar, the induration of which depends on the gradual intimate combination which the lime forms with the water; and in practical chemistry, and many of the chemical arts, it admits of numerous applications from its chemical agencies. It is highly corrosive, erodes and dissolves animal matter, and hastens the decomposition of a number of vegetable products.

The following table exhibits the constitution of the principal compounds of calcium and of lime:



## COMPOUNDS OF CALCIUM.

	Calcium, 1 atom = 20.	Weight of the other body.	Equivalent of the compound.
Chloride, .....	20	36	56
Iodide, .....	20	124	144
Oxide, (lime,) .....	20	8	28
Phosphuret, .....	20	12	32
Sulphuret, .....	20	16	36

## SALTS OF LIME.

	Lime, 1 atom = 20.	Acid.	Water, 1 atom = 9.	Equivalent of the salt.
Acetate, .....	28	50		78
6 water, .....	28	50	54	132
Arsenate, .....	28	62		90
Benzoate, .....	28	120		148
Carbonate, .....	28	22		50
Chlorate, .....	28	76		104
Chloride, .....	28	36		64
subchloride, 6 water, .....	56 (2 at.)	36	54	146
Chromate, .....	28	52		80
Citrate, .....	28	58		86
Fluate, .....	28	10		38
Hydriodate, .....	28	125		133
Hydrosulphuret, 5 water, .....	28	17	45	90
Bin-Hyposulphite, 6 water, .....	28	48	54	130
Iodate, .....	28	164		192
Muriate, cryst. 6 water, .....	28	37	54	119
Nitrate, .....	28	54		82
3 water, .....	28	54	27	109
Oxalate, .....	28	36		64
2 water, .....	28	36	18	82
Phosphate, .....	28	28		56
bi-phosphate, .....	28	56		84
Phosphite, .....	28	20		48
Succinate, .....	28	50		78
Sulphate, (anhydrous,) .....	28	40		68
cryst. 2 water, (gypsum,) .....	28	40	18	86
Sulphite, .....	28	32		60
Tartrate, .....	28	66		94
4 water, .....	28	66	36	130
Tungstate, .....	28	150		178



## CHAP. IV.

## OF MAGNESIA.

THIS earth, in the state of carbonate, had been employed in medicine, and had been considered as analogous to carbonate of lime. Hoffman observed, that it forms with sulphuric acid a salt very different from sulphate of lime. And Dr Black, discovering its principal properties, proved it to be essentially different from the other earths.

It is not much affected by galvanism, probably from the difficulty of rendering it a conductor of electricity. But when some of its saline compounds are submitted in the usual manner, in contact with quicksilver, to galvanic action, an amalgam is obtained, which appears to contain the metallic base of magnesia, as this earth is formed on its surface by exposure to the air. From this amalgam, Sir H. Davy found it difficult to expel the whole of the quicksilver, the glass tube in which heat was applied to it being acted on. In one experiment, a solid was obtained, having the white colour and the lustre of the metallic bases of the other earths, which sunk rapidly in water, producing magnesia, and was also covered with a crust of magnesia on exposure to the air. To this metallic base, the name of *MAGNESIUM* may be given.

Magnesia, under various states of saline combination, exists in nature in considerable quantity. It is found, in particular, in the water of the ocean, united with sulphuric and muriatic acids; and the same salts frequently exist in mineral springs. From either of them the magnesia may be procured, by adding to their boiling solution an alkaline carbonate; the carbonate of magnesia is precipita-



ted, and being thoroughly washed and dried, the carbonic acid may be expelled from the magnesia by exposure to a red heat.

Magnesia obtained by this process is in the form of a white spongy powder, not three times heavier than water, very soft to the touch, inodorous, and having a weak earthy taste: it is composed of one atom of magnesium 12, and one of oxygen, 8; its equivalent is therefore 20. It slightly changes the blue vegetable colours to a green. It is infusible when exposed even to very intense heats. If previously made into a paste with water, it suffers contraction when exposed to a sudden heat.

It is insoluble in water; when dry, it absorbs a portion of water, but does not form with it a ductile paste. When it is precipitated from any of its saline solutions by potash, it retains in drying a kind of gelatinous consistence, by retaining water in weak combination. This forms perhaps a hydrate of magnesia, which, according to Davy, contains nearly a fourth of its weight of water. A hydrate appears to exist as a mineral production, composed, according to Dr Fyfe, of magnesia 69.75, and water 30.25, which is nearly the proportion of one atom of the earth, 20, and one of water, 9; it has a crystalline structure.

Neither magnesium nor magnesia unite with sulphur in the dry way. Magnesia combines with the acids: its salts are in general very soluble and crystallizable, and have a bitter taste. They are decomposed by the fixed alkalis and the alkaline earths, the magnesia being precipitated. Their decomposition by ammonia is partial; this alkali having a tendency to form with the magnesia and acid, soluble ternary compounds.

CARBONATE OF MAGNESIA is prepared for medicinal use by dissolving equal weights of sulphate of magnesia



and carbonate of potash separately in twice their weight of water; mixing them together, and diluting with eight parts of warm water: the magnesia attracts the carbonic acid; and the compound being insoluble, is precipitated, while the sulphate of potash that is formed remains in solution. The mixture is made to boil for a few minutes; after cooling a little, it is poured upon a filtre; the clear fluid runs through, and the precipitate of carbonate of magnesia is washed with water till it is tasteless. When the process is conducted on the large scale, the bittern or liquor remaining after the crystallization of sea-salt, which is principally a solution of muriate and sulphate of magnesia, is substituted for the pure sulphate, and this is precipitated by a solution of pearl-ash, or of carbonate of ammonia procured by distillation from animal substances. Carbonate of magnesia is perfectly white, friable, and nearly tasteless. It is very sparingly soluble in water, requiring at least 2000 times its weight, at the temperature of  $60^{\circ}$ . When acted on by water impregnated with carbonic acid, it is dissolved; and from this solution, allowed to evaporate spontaneously, the carbonate of magnesia is deposited in small prismatic crystals, which are transparent and efflorescent: they are soluble in 48 parts of water at  $60^{\circ}$ . They contain three atoms of water; whereas the native carbonate is anhydrous; according to Dr Thomson, however, they also become anhydrous on exposure to the air.

NITRATE OF MAGNESIA has a taste bitter and acrid. Its crystallization exhibits a mass of needle-like crystals, deliquescent, soluble in half their weight of water at  $60^{\circ}$ .

SULPHATE OF MAGNESIA is found in sea-water, and in many mineral waters, and is usually extracted from the brine of sea-water, Bittern as it is named, this being boiled



down until it afford the sulphate of magnesia, on cooling, in acicular crystals: or sulphate of iron is added, the sulphuric acid of which combines with the magnesia of the muriate of magnesia, and increases the quantity of sulphate. Obtained in this way, it exhibits a confused mass of needle-like crystals, which are deliquescent; but this is owing to the admixture of muriate of magnesia, as the pure sulphate is rather efflorescent. By slow evaporation of its solution it crystallizes in quadrangular prisms, acuminated by four planes: these crystals are soluble in little more than their own weight of water at 60°, and in three-fourths of their weight of boiling water. They contain more than half their weight of water, or about 7 atoms of it; hence they undergo the watery fusion at a very moderate temperature. The taste of this salt is very bitter, and the bitterness of sea-water and many mineral springs is owing in part to its presence.

**SULPHATE OF MAGNESIA AND SODA.** In the process of purifying the sulphate of magnesia, which is obtained by evaporation from the bittern of sea-water, a salt sometimes crystallizes which is possessed of peculiar properties. On submitting it to analysis, I found it to be a triple compound of sulphuric acid with magnesia and soda; it crystallizes in rhombs, at first irregular and semi-transparent, but by a second crystallization it is obtained in more regular rhombs, truncated on the edges and transparent. I found it to consist, in 100 parts, of sulphate of magnesia 32, sulphate of soda 39, water of crystallization 29.\*

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\* The proportions of the constituents of this triple salt, here given by Dr Murray, are very nearly those of one equivalent of sulphate of magnesia, 60, one of sulphate of soda, 72, and six of water, 54; its equivalent is therefore 186.



As its taste is not disagreeable, and it is a purgative salt of considerable activity, it may be employed with advantage in medicine \* ; it is not improbable even that it exists as a triple salt in some of the purgative mineral waters.—**SULPHATE OF MAGNESIA AND AMMONIA.** This salt is described by Fourcroy as formed by adding ammonia to a solution of sulphate of magnesia. It crystallizes in octohedrons, which are less soluble in water than either of the binary salts.—**SULPHITE OF MAGNESIA** is soluble and crystallizable ; it is decomposed by heat, and by exposure to the air it changes into a sulphate. **HYPO-SULPHITE OF MAGNESIA** has a very bitter taste, is very soluble in water, but is not deliquescent. Thrown on a hot iron, it takes fire and burns with a feeble flame.—**PHOSPHATE OF MAGNESIA**, formed from the combination of the acid and the earth, crystallizes in prisms which are efflorescent, soluble in about 15 parts of cold water, and which by heat melt into a glass. A triple Phosphate of Magnesia and Ammonia exists, which is formed by adding phosphoric acid with ammonia in excess to a magnesian salt. It is insoluble, and is precipitated in a soft white powder of shining lustre ; it forms one variety of urinary calculus : and its formation affords the best test of discovering magnesia. It consists of one atom of magnesia, 20, one of ammonia, 17, and two of phosphoric acid, 56 ; its equivalent is therefore 93. When crystallized it contains 4 atoms of water, and its equivalent is then 129.—**BORATE OF MAGNESIA** is obtained by evaporation, in a crystalline mass : it forms the mineral named Boracite.—**MURIATE**

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\* An empirical purgative remedy has accordingly been sold under the name of " Lymington Glauber's Salts," which consists wholly of this triple salt.



OF MAGNESIA has such an affinity to water, that it can be obtained in acicular crystals only by exposing its concentrated solution to sudden cold: these crystals are very deliquescent, and dissolve in less than their weight of water. No chloride of magnesium can be obtained by heating this salt; for the acid is expelled from it undecomposed, by the application of heat.—CHLORIDE OF MAGNESIA may be formed in the same manner as chloride of lime. It has the same bleaching power, and it has been proposed to apply it to the same purpose. When the chloride of lime is used, a small quantity of lime is left in the cloth: this, in the last operation of washing the cloth with water acidulated with sulphuric acid, is converted into sulphate of lime, which, being insoluble, remains and affects the colours when the cloth is dyed. The advantage of employing the chloride of magnesia is, that if sulphate of magnesia is formed, it is so soluble as to be easily removed by washing.—HYDRIO-DATE OF MAGNESIA is stated by Gay-Lussac to be deliquescent, and difficultly crystallizable: like the muriate it is not convertible by heat into an iodide of magnesium.

Magnesia is scarcely applied to any use, except in medicine as an antacid and lithontriptic. Some of the native combinations of it with other earths have been used in the manufacture of porcelain, and prove useful by lessening the tendency to contraction in the baking of the earthy composition.

The composition and atomic weights of the principal salts of magnesia are stated in the following Table:



## SALTS OF MAGNESIA.

	Magnesia. 1 atom=20.	Acid.	Water. 1 atom=9.	Equivalent of the salt.
Acetate, .....	20	50		70
Cryst. 5 water, .....	20	50	45	115
Arseniate, .....	20	62		82
Cryst. 8 water, .....	20	62	72	154
Bi-borate, (boracite,) .....	20	48		68
Carbonate, (anhydrous native,) ....	20	22		42
Cryst. 3 water, (artificial,) .....	20	22	27	69
Chloride, .....	20	36		56
Chromate, .....	20	52		72
Muriate, cryst. 5 water, .....	20	37	45	102
Nitrate, cryst. 6 water, .....	20	54	54	128
Oxalate, 2 water, .....	20	36	18	74
Binoxalate, cryst. 7 water, .....	20	72	63	155
Phosphate, .....	20	28		48
Cryst. 7 water, .....	20	28	63	111
Sulphate, ... ..	20	40		60
Cryst. 7 water, .....	20	40	63	123
Tartrate, .....	20	66		86
2 water, .....	20	66	18	104
Bitartrate, cryst. 1 water, .....	20	132	9	161

## CHAP. V.

## OF ALUMINA.

THIS earth is the base of the clays, whence the name of Argil has been given to it. Being the base of the salt, known by the name of Alum, it has also received the appellation of Alumina. Though it exists in nature nearly in a state of purity, forming the sapphire and some other gems, its state of aggregation, in these forms of it, disguises its chemical properties; and it is therefore as obtained by an artificial process that it is usually described.

The decomposition of this earth by galvanism has been very imperfectly effected. The usual methods proved un-



successful, and Sr H. Davy obtained only imperfect indications by another method,—submitting the alumina to galvanic action in a state of fusion with potash or soda: an alloy was, however, formed, which, when thrown into water, produced a little alumina. By passing the vapour of potassium over the earth heated to whiteness, small particles of a grey colour and metallic lustre were obtained, which became white on exposure to the air.

The artificial process by which argillaceous earth is usually obtained, consists in dissolving common alum in water, and decomposing it by the addition of ammonia, which combines with the acid of the alum, and precipitates the earth which is its base. To this a little of the acid may however adhere; to remove which, the precipitate, after having been thoroughly washed, is redissolved in nitric acid, precipitated a second time by ammonia, and after being washed and dried is exposed to a red heat. Another method that has been recommended is to form a muriate of alumina, and precipitate the earth from the solution by ammonia.

Alumina, obtained by these processes, is in the state of a light white powder, spongy and soft. It is peculiarly distinguished by forming with water a paste, which, when kneaded, is tenacious and ductile; and it is from the presence of this earth that the natural clays derive their plastic quality. Though no sensible quantity of it is dissolved by water, it forms with it an imperfect combination; the loose precipitate, from the decomposition of dilute solutions of its salts, being somewhat gelatinous, and, even in drying, forming a kind of transparent brittle mass: if precipitated from a concentrated solution, it forms, when dried, a loose powder. The latter has been named Spongy, the former Gelatinous Alumina: it retains the water it has imbibed, so strongly, that even exposure to a



red heat does not entirely expel it. It is therefore a hydrate of alumina, and appears to contain one-third of its weight of water. A native hydrate exists, containing a larger proportion.

The paste formed by kneading this earth with water, contracts from the application of heat; the contraction, as has already been stated, in considering the application of this to pyrometry, continuing to proceed even at the most intense heats, long after the whole of the water has been expelled. The clay at the same time acquires a great degree of hardness from its augmented aggregation. This earth is almost infusible; it has been melted, however, in minute quantities, by the heat excited by a stream of oxygen gas directed on burning charcoal. An important property of this earth, which will be afterwards noticed, is its affinity to colouring matter.

Alumina combines more readily than the other earths with the alkalis. When its salts are decomposed by potash or soda, an excess of either added redissolves the precipitate, forming with the acid a ternary compound. They can dissolve alumina alone; and they form with it by fusion a species of combination, in which the earth is rendered soluble in water. Alumina exerts affinities to the other earths, both in the humid way and by fusion. Barytes and strontites render it soluble in water. It exerts an affinity to magnesia, in consequence of which it aids its precipitation from saline compounds. It unites in the humid way with silex, and, what is a singular effect, renders this earth soluble in acids; it also combines with it by fusion. The combination of alumina with silex by fusion, forms the basis of Pottery and Porcelain, at least these two earths form the essential ingredients; the alumina communicates to the mixture that plastic quality, in consequence of which, the paste formed with water can



be turned on the lathe ; the silex prevents this paste from contracting too much in drying ; and when heat is applied, the two earths unite, rendering each other more fusible, so as to pass into that state of vitrification which forms Porcelain. Natural clays, which are mixtures of these two earths more or less pure, are used in the manufacture, and require to be variously proportioned by intermixture. The composition is freed from impurities, is levigated, and kneaded with water into a ductile paste. This is turned on the lathe into the requisite forms ; the vessels are afterwards dried, and baked in a furnace with a fire gradually raised ; their surface is glazed by their being previously dipt into an earthy composition more fusible than that which forms the base ; or frequently by throwing common salt into the furnace. By the combination which the heat establishes, an imperfect vitrification is produced, forming a white semitransparent enamel, which constitutes porcelain, while the surface is more completely vitrified and rendered more smooth. Porcelain has the hardness and compactness of glass, is less brittle, and more capable of bearing sudden alterations of temperature, and has much beauty from its whiteness and semitransparency. The colours are usually formed from metallic oxides, which are mixed with fluxes to render them sufficiently fusible, and are applied by a pencil before the porcelain is baked.

The coarser clays, containing, besides silex and alumina, lime and iron, form the inferior kinds of porcelain and pottery. From their greater fusibility, they cannot sustain so high a heat, and are therefore glazed by more fusible materials, mixtures of earthy matter with glass, and often with oxide of lead.

There has been considerable difficulty in determining the combining weight of alumina ; and it is still in some



degree uncertain. The chief cause of this uncertainty is, that alumina exerts weaker affinities than almost any other of the earths; its compounds are hence less distinct and definite. Another circumstance which renders it difficult to estimate the quantity of this earth in any of its salts is, that it unites with acids in a number of different proportions, in conformity with an observation of Berzelius, that bases of little activity have the property of combining with acids in a greater number of proportions than energetic ones. According to Mr R. Phillips, its atomic weight is 27 to hydrogen as 1; according to Dr Thomson, it is 18: the latter appears to be the more probable number; subtracting 8 from it, for an equivalent of oxygen, we obtain 10 for the atomic weight of aluminum.

Alumina combines with the acids, neutralizing most of their properties: its salts, however, in general, exhibit the acid property of reddening vegetable colours. Those which are soluble have a sweetish, and at the same time astringent taste. They are decomposed by the alkalis and alkaline earths.

CARBONATE OF ALUMINA can scarcely be formed: water impregnated with carbonic acid dissolves a portion of the earth; but in evaporating the solution, the carbonic acid is expelled.

NITRATE OF ALUMINA.—The solution of alumina in nitric acid becomes gelatinous on evaporation, and soft crystalline scales are formed, having a taste sour and astringent, easily soluble in water, and deliquescent. They contain, according to Dr Thomson, no less than 10 atoms of water of crystallization. When heated, part of the acid is expelled, and a sub-nitrate remains.

SULPHATE OF ALUMINA, formed by dissolving the earth in sulphuric acid, is very soluble in water; on evaporation it assumes a gelatinous consistence. It consists of an atom



of acid and one of earth, with 7 atoms of water. A subsulphate of alumina occurs native, containing 3 atoms of earth to 1 of acid.

This salt, known by the name of Alum, is a ternary compound of alumina, potash, and sulphuric acid. In some of the varieties of the alum of commerce, ammonia even enters into the composition, and it is often contaminated with a little sulphate of iron. Alum is a natural product, occurring efflorescent in the layers of what has been named Alum Slate: it is also formed by an artificial process, from what is named Alum Ore, which appears to be a variety of slate impregnated with sulphur or sulphuret of iron; this slate is calcined, and afterwards exposed to the atmosphere in a humid state; the sulphur absorbing oxygen is converted into sulphuric acid, which acts on the argillaceous earth of the slate. The saline matter is extracted by lixiviation, and when a little potash has been added, alum is obtained by crystallization. The alum of commerce is in large masses, white and transparent. When regularly crystallized, the form of the crystals is an octaedron. It is soluble in 15 parts of cold, and in two parts of boiling water: its crystals are slightly efflorescent: its taste is sweetish and astringent: its solution reddens the vegetable colours. When exposed to a moderate heat it melts, from the water of crystallization which it contains dissolving the solid salt; this soon evaporates, and leaves a light white powder, named Burnt or Calcined Alum. By a strong heat the acid is partly expelled, partly decomposed, a quantity of oxygen being afforded by its decomposition. This salt is decomposed by the alkalis and alkaline earths, which attract the greater part of the acid, and precipitate the earth with a small quantity of acid combined with it. With regard to the constitution of alum, there is a difference of opinion arising from the uncertain-



ty respecting the atomic weight of alumina. According to Mr Phillips, it consists of

1 atom of bi-sulphate of potash, .....	128
2 atoms of sulphate of alumina, (each atom 67), .....	134
25 atoms of water, (each atom 9), .....	225
	<hr/>
	487

According to Dr Thomson, it contains no bi-sulphate of potash, but is composed of

1 atom of sulphate of potash, .....	88
3 atoms of sulphate of alumina, (each atom 58), .....	174
25 atoms of water, .....	225
	<hr/>
	487

The only difference between these views is, that the latter supposes 3 atoms of alumina to exist in alum, each weighing 18, while, in the former, only 2 atoms are admitted, each weighing 27. The question can be decided only by the determination of the real atomic weight of this earth. As the analysis of others of its salts, and of a number of crystallized minerals are in favour of the opinion, that 18 represents the equivalent of alumina, Dr Thomson's view may be adopted as the more probable one.

The sulphuric acid of alum is decomposed by heating it with carbonaceous matter. A decomposition of this kind affords a very peculiar product, distinguished by burning spontaneously on exposure to the air. This substance, named Pyrophorus, is prepared by exposing to heat in an iron pot, two parts of alum, with one part of flour: the mixture liquefies, and is to be stirred constantly till the whole becomes grey, and easily reducible to powder while hot. The coarse powder is put into a coated phial, so as nearly to fill it, and this slightly stopped with clay, being surrounded with sand in a crucible, is

58

67



exposed to a red heat, until a blue flame appears at the mouth of the phial : when this has continued ten minutes, the crucible is removed from the fire, and the phial when sufficiently cold, is accurately stopt.

Pyrophorus inflames in atmospheric air, especially in a moist atmosphere. It burns brilliantly in oxygen gas, in nitrous gas, and chlorine gas, and is inflamed by sulphuric and nitrous acids. With regard to the theory of its combustibility, it has been proved, that in order to form it the alum must contain potash ; the sulphuric acid is decomposed by the carbonaceous vegetable matter, and a portion of its sulphur is supposed to combine with potassium, and form a sulphuret, which is diffused through the argillaceous earth, with a quantity of charcoal perfectly dry. When exposed to the air, moisture is absorbed, by which the temperature is raised : and the sulphur, it is supposed, absorbing oxygen, is inflamed, and kindles the dry carbonaceous matter. It is not improbable, as Davy has suggested, that a portion of the potash may be decomposed by the joint action of the sulphur and charcoal, and free potassium produced, to which the combustibility may be principally owing.

Alum is used in a variety of arts. It hardens tallow : it increases the adhesive power of the farinaceous pastes : it renders turbid water clear, and it is an essential article in the art of dyeing, fixing the colours, and often adding to their brilliancy. The presence of iron often injures the more delicate colours, and the superiority of the variety called Roman Alum, as a mordant, appears to be owing to its being free from this metal. Alum is also used in medicine as a powerful astringent. Sulphuric acid and alumina form triple compounds also with ammonia and with soda, analogous to common alum.

PHOSPHATE OF ALUMINA forms an insipid powder: it



melts before the flame of the blow-pipe into a transparent globule. The beautiful mineral named Wavellite consists chiefly of it.—MURIATE OF ALUMINA can scarcely be crystallized, its solution becoming gelatinous on evaporation; when dried by heat its acid leaves it in the gaseous form; there is thus no chloride of aluminum.—CHLORIDE OF ALUMINA. This compound has been formed by Mr Wilson by mixing a solution of chloride of lime with a solution of alum; sulphate of lime is precipitated, and chloride of alumina remains in solution. It has been found, that this compound discharges the Turkey red dye, which is so permanent, that it resists the action of all the other chlorides. It is thus nearly as powerful in this respect as the solution of chlorine itself, while it is not so injurious to the cloth, nor of so offensive an odour.—FLUATE OF ALUMINA is not soluble, but is rendered so by an excess of acid. It forms the greater part of the rare mineral named Cryolite.

## SALTS OF ALUMINA.

	Alumina.	Acid.	Water.	Equivalent. of the salt.
Acetate, cryst. 1 water, .....	18	50	9	77
Arsenate, .....	18	62		80
Cryst. 6 water, .....	18	62	54	134
Fluate, .....	18	10		28
Muriate, cryst. 3 water, .....	18	37	27	82
Nitrate, (subnitrate or dinitrate, Thomson,) cryst. 10 water, .....	36(2 at.)	54	90	180
Subnitrate, (trisnitrate, Thom- son,) 6 water, .....	54(3 at.)	54	54	162
Oxalate, 3 water, .....	18	36	27	81
Phosphate, .....	18	28		46
3 water, .....	18	28	27	73
Sulphate, 7 water, .....	18	40	63	121
Subsulphate, (trisulphate, Thom- son,) 9 water, . . . . .	54(3 at.)	40	81	175
Sulphate of potash and, (alum) dry,	54+48	160(4 at.)		262
Crystallized alum, 25 water, .....	54+48	160	225	487
Tartrate, .....	18	66		84
1 water, .....	18	96	9	93



## CHAP. VI.

## OF SILEX, OR SILICA.

THIS earth is one very extensively diffused ; it forms the principal constituent part of most of the fossils and rocks of which the solid crust of the earth is composed ; and those in which it predominates having usually a considerable hardness, and the silex itself being altogether insoluble in water, and in its usual state of aggregation not easily diffused through it, it remains when they have been disintegrated or decomposed : hence the sand of rivers and of the sea-shore is principally composed of it. Rock crystal, quartz, and flint, are fossils in which it exists almost perfectly pure, though in these its state of aggregation modifies its chemical properties, which are rather determined therefore from it in the state in which it is obtained by an artificial process.

The decomposition of this earth by galvanic action is very imperfect : when submitted however to the action of potassium at a red heat, a brownish coloured substance was obtained mixed with potash, which, dropt into water, gave indications of the regeneration of silex. Even this result gave no information as to the characters of this base. It has, however, been lately obtained by Berzelius in an insulated form, and its properties, which are extremely singular, determined. He procured this base, Silicium as it is termed, when attempting to decompose siliceo-fluoric acid, by heating potassium in it. The potassium burns, and condenses the acid gas, and during the combustion a brown substance appears, which when purified from adhering silica and fluoric acid is silicium. It



may be obtained more easily by heating potassium with the dry siliceo-fluate of potash, washing the product with water, heating it to expel a portion of hydrogen which exists in it, and lastly digesting it in dilute fluoric acid, which removes any undecomposed silica from it; a brown substance remains, which is this base.

Pure Silicium thus procured is a substance very different from what might have been expected. From the difficulty of abstracting oxygen from the earth, it might have been supposed that the base would, like potassium, sodium, &c. attract oxygen with avidity from any source which could afford it, but, on the contrary, in a great number of instances, it shows no disposition to unite with oxygen: thus it does not burn in atmospheric air, though strongly heated; it may be exposed to the flame of the blowpipe without suffering any change: it is even incombustible in oxygen gas. It is not oxygenated, or in any way altered by water, sulphuric or nitric, or even nitromuriatic acid, nor by caustic potash: a mixture of nitric and fluoric acids, however, dissolves it. It suffers no change by being heated with chlorate of potash. In chlorine gas it burns when raised to a red heat, and a yellowish fluid is formed, which has an odour somewhat resembling that of cyanogen: on the addition of water silica is produced, forming a gelatinous precipitate. When silicium is heated in the vapour of sulphur, combination ensues with an emission of light: when the compound is thrown into water, sulphuretted hydrogen is rapidly evolved, and silica partly dissolved and partly deposited.

Silicium is oxidated, however, with rapidity, whenever an alkali, as potash or soda, is present, which having an attraction to silica favours the formation of the earth, by a disposing or resulting affinity. Accordingly, when this base is heated with carbonate of potash it burns vividly,



expelling the carbonic acid. With the hydrates of potash or soda, it even explodes at a temperature much below redness, hydrogen being disengaged, and the silica produced uniting with the alkali. Heated with nitrate of potash, no action happens till the heat decomposes the acid, and liberates the potash.

In these respects Silicium differs strikingly from the bases of the alkalis and other earths. Its other properties are equally anomalous. Thus, all these bases are either metallic or approach very closely in characters to metals; but silicium has not the slightest metallic lustre, and is a non-conductor of electricity. In these characters it is conceived to resemble some of the inflammables, and to bear indeed a greater analogy to carbon and boron than to perhaps any other substances. Accordingly, it has been considered by Sir H. Davy and Dr Thomson, rather as an inflammable than a metal; and its oxide, silica, having little or no tendency to unite with acids, while it has considerable affinity to various salifiable bases, has been regarded as an acid, and its compounds have been termed *Silicates*. For this opinion there appears to be little foundation. The mere fact of a substance uniting with alkalis and earths, which is the only title that a number of substances at present termed acids have to that character, is no decisive proof of acidity, as the alkalis and earths enter into union with each other, and with metallic oxides, and might hence be themselves denominated acids. Silica, moreover, in its inertness, insolubility and other properties, is closely connected with the other earths; and with regard to its base, if the substance which has been described be really its base, which from its singular characters is in some measure doubtful, it matters little whether it be placed among the inflammables or metals, as it has little analogy to either of them. The atomic weight



of silicium is inferred by Dr Thomson, to be 8, or equal to that of oxygen; the equivalent of silica is therefore 16.

The process by which Silex, or Silica as it is sometimes named, is usually obtained, consists in fusing calcined flint with four times its weight of carbonate of potash. The mass, when cold, is dissolved in water, and diluted sulphuric acid is added to the clear solution as long as any precipitation ensues; the precipitate is washed with water, and dried. It appears, however, not to be pure silex, but to retain a portion of alkali in combination. Colourless rock-crystal, pounded, probably affords it more pure.

Silex procured by precipitation is in the form of a light white powder, insipid and gritty to the touch; when mixed with water, it does not form an adhesive paste. It is so infusible, as to melt only in the intense heat excited by an inflamed mixture of hydrogen and oxygen gases.

It is not dissolved in any appreciable quantity by water, yet there are facts which prove its solubility to a certain extent when this is not counteracted by its aggregation: if the solution of its compound with potash be decomposed by an acid, no precipitate appears, if the solution has been previously very largely diluted with water, though otherwise it would be apparent; and it exists in solution in some mineral springs, as in the Geyser fountains of Iceland, in which no substance that can contribute to its solution can be detected. When newly formed by the oxygenation of its base, Berzelius found it to be extremely soluble.

This earth combines with the fixed alkalis, either by being boiled with them in water, or by fusion from heat. When one part of flint or quartz is melted with three parts of carbonate of potash, the carbonic acid is expelled, and the compound of silex and potash is partially soluble



in water: with pure potash the combination is more perfect. The solution of silicated potash, or soda, *Liquor Silicum* as it is named, becomes gelatinous when concentrated by evaporation. When kept for a number of years, crystals have been observed to be deposited from it, transparent and hard. It is decomposed by all the acids, the silica being precipitated; a little of it is, however, retained in solution by the acids: hence, when it is requisite that all the silica that may be in a solution shall be precipitated, Dr Marcet recommends that muriate of ammonia should be employed.

With a smaller proportion of alkali to the silex, the compound is less soluble, and a stronger heat is required for its vitrification: it may even be obtained altogether insoluble, transparent, and possessed of considerable hardness. Such a combination constitutes *GLASS*, the essential parts of which are siliceous earth, and potash or soda. The proportions are about two parts of the earth, to from one to one and a half of the carbonate of potash of commerce: they are intimately mixed, and the mixture is exposed to a heat sufficiently strong to expel the water and carbonic acid, and effect an imperfect combination. This is completed by afterwards applying a stronger heat, so as to produce perfect fusion, the impurities and unvitrified matter being drawn off. The glass thus formed is more transparent and colourless, as the materials have been pure. Green glass is prepared from sand and kelp, or the residuum of the soap-makers' ley; white crystal glass, as it is named, is prepared from pounded flint or a very white sand; and to this there is an addition of oxide of lead to promote the vitrification, and add to the density, and also to increase the lustre by giving a higher degree of refractive power. A little oxide of manganese is added to remove the green tint liable to be produced from the presence of oxide of iron.



Glass in fusion has a great degree of tenacity and ductility, so that it can be easily cast in a mold, and cut and wrought in a variety of shapes. It loses this in cooling; and if cooled hastily is so brittle, that the slightest impulse or agitation is sufficient to cause it to fall into fragments. This is in part prevented by slow cooling, by which a different arrangement of the particles of the glass is allowed to be assumed. This slow cooling, by which glass is rendered less brittle, is termed the *annealing* of glass. It appears even, that if the cooling be performed very slowly, the particles pass into such an arrangement that the glassy character is entirely lost, and the mass becomes opaque, and displays in its fracture a crystalline structure. Glass thus devitrified may have its transparency and other usual properties restored by melting it, and cooling it more quickly.

Glass when prepared without an excess of alkali, is permanent in the air, and is scarcely acted on by any chemical agent. Fluoric acid, from its action on silex, erodes and even dissolves it. The fixed alkalis fused with it render it soluble in water; and the metallic bases of the alkalis decompose it, by partially abstracting the oxygen of the alkali, which enters into its composition, and perhaps also of the silex itself. When glass is exposed to heat, imbedded in various earthy mixtures, it loses its transparency, and becomes like porcelain; this is called Reaumur's porcelain; it is more hard, less fusible, and better capable of bearing sudden alterations of temperature than transparent glass, changes depending partly perhaps on the operation of slow cooling connected with the process. Glass made from very pure materials, with the addition of borax and oxide of lead, and coloured by the addition of other metallic oxides, forms imitations of the gems. The transparency and colours of these are often equal to



those of the real gems, but they are greatly inferior in lustre and hardness.

Silex exerts affinities to the other earths, and combines with the greater number of them by fusion, forming glasses generally more or less opaque. These affinities too are frequently exerted in the humid way. Thus silex is precipitated from its solution in potash, by the attraction exerted to it by barytes, strontites, and lime.

This earth is scarcely soluble in the acids, nor does it form with any of them neutral compounds, a character by which it is peculiarly distinguished. By fusion it combines with boracic and phosphoric acid, forming a species of glass; when in a state of extreme division, muriatic acid appears to dissolve a small quantity of it. Fluoric acid is its proper solvent, dissolving it either when the acid is gaseous, or when combined with water; and this combination seems to take place in different proportions, as has been already stated.

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## CHAP. VII.

### OF ZIRCON.

THE earth to which this name has been given, was discovered by Klaproth in a fossil, the Zircon or Jargon, brought as a gem from Ceylon. It has since also been discovered in the Hyacinth. It is obtained from the zircon by calcining it repeatedly to diminish its force of aggregation, reducing it to fine powder, and then fusing it with six times its weight of potash; the fused matter is dissolved in water, and to the solution muriatic acid is



added in slight excess, boiling for a short time to precipitate more effectually the silex, with which the other earth is combined. The filtered liquor is evaporated to dryness, and redissolved; it is then decomposed by the addition of carbonate of soda; the carbonate of zircon which is precipitated is dried, and the carbonic acid is expelled by heat.

This earth, submitted to the action of galvanism, in contact with potassium, afforded a dark coloured matter, which, when acted on by water, yielded a minute portion of zircon. This base was accordingly denominated zirconium, but the results were too imperfect to discover its properties. It has lately been obtained by Berzelius, by a method similar to that by which he procured silicium. He describes it as of a deep black colour, as not oxidated by water or muriatic acid, but dissolved by nitro-muriatic and fluoric acids. It is not so inert as silicium, however, for when slightly heated in the air it burns brilliantly. It forms with sulphur a brown compound, insoluble in alkalis and in muriatic acid, and which also burns vividly, being converted into sulphurous acid and zircon.

Zircon, obtained by the above process, is a white powder, insipid, and rough. When exposed, imbedded in charcoal, to the violent heat of a forge, it undergoes a semi-vitrification; becomes so hard as to give fire with steel; has a brilliant vitreous fracture; and is of a grey colour. Its specific gravity in this state is 4.3. When the powder is mixed with water, it imbibes it, and forms a semi-transparent jelly, and it retains so much of this in drying, as to form a substance in appearance like gum. Dr Thomson considers zircon to consist of one atom of zirconium, 40, and one of oxygen, 8; its equivalent is therefore 48.

Zircon is insoluble in the liquid alkalis, but is dissolved by the alkaline carbonates.



Zircon combines with the acids, and forms salts in general sparingly soluble. Those which are soluble have a sweetish astringent taste. Its affinities to the acids appear to be weak, as its salts are in general decomposed by a low heat, as well as by the alkalis, and all the other earths. Triple prussiate of potash and iron throws down from its solutions a greenish blue precipitate, rendered more blue by muriatic acid, but afterwards changed to green. Hydro-sulphuret of ammonia throws down a dark olive precipitate. Professor Pfaff has remarked, that there is a striking resemblance in chemical relations between zircon and oxide of titanium. The chief difference between them is, that tincture of galls throws down from solutions of the former a yellow, of the latter a reddish brown precipitate.

CARBONATE OF ZIRCON is insoluble, and is decomposed by heat.—NITRATE OF ZIRCON is a transparent resinous-like matter, not easily dried, having an astringent taste.—SULPHATE OF ZIRCON is insipid and insoluble.—PHOSPHATE OF ZIRCON is insoluble.—MURIATE OF ZIRCON is soluble, and affords, by evaporation of its solution, transparent needle-like crystals.

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## CHAP. VIII.

### OF GLUCINE.

THIS earth was discovered by Vauquelin, forming a constituent part of the beryl and of the emerald. He gave it the name of glucine, derived from the property it has of forming salts having a sweet taste. The process by which he obtained it from the beryl, was to fuse one part of it



with three parts of potash ; the mass, after cooling, was dissolved in muriatic acid : the solution was evaporated to dryness, and on again dissolving the matter in water, the silex present remains undissolved. The solution is decomposed by carbonate of potash : the precipitate is digested with a solution of pure potash ; the greater part of it, consisting of argil, together with a portion of glucine, is dissolved ; but there remains a portion undissolved, which is the glucine, sometimes coloured by a little oxide of iron.

Davy, in attempting the decomposition of glucine, obtained results similar to those from zircon, an amalgam being formed, when it had been placed in the galvanic circuit with mercury and potassium which decomposed water, and which reproduced glucine, when the alkali in the liquid was neutralized by an acid. A similar result was obtained on submitting it to the action of potassium at a high temperature.

Glucine obtained pure is white, and soft to the touch ; it adheres a little to the tongue ; it is insipid ; is infusible ; is insoluble in water, but forms with it a paste which is somewhat ductile ; this paste is not hardened by heat, nor does it contract like alumina. Its specific gravity is 2.96. Its combining weight appears to be 26.

Glucine is soluble in the fixed alkalis, but not in ammonia ; it is dissolved, however, in carbonate of ammonia, forming a triple salt,—a property so far characteristic of it, though possessed also by zircon. It is dissolved also by the other alkaline carbonates. It decomposes the salts of alumina. Glucine combines readily with the acids. Its salts are generally soluble, and have a sweet taste, with some degree of astringency. They are decomposed by the alkalis : the earth is even completely precipitated by ammonia, a test which distinguishes it



from alumina, to which it has otherwise some resemblances. Its salts are not precipitated by the alkaline prussiates.

CARBONATE OF GLUCINE is insipid and insoluble in water.—NITRATE OF GLUCINE, by evaporation forms a gelatinous mass, which is very deliquescent.—SULPHATE OF GLUCINE is difficultly crystallizable; its taste is saccharine and astringent; it is very soluble.—MURIATE OF GLUCINE is soluble in water, and by evaporation can be obtained in small crystals.

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## CHAP. IX.

### OF YTTRIA.

THIS earth was discovered by Gadolin, a Swedish chemist, in a fossil found at Ytterby in Sweden, since named Gadolinite, in which it is combined with silex and lime. It has also been discovered in some other fossils. In several of its properties it resembles glucine, but it differs entirely in others. The process followed by Vauquelin to obtain the earth from the gadolinite, was to dissolve it with the assistance of heat in diluted nitric acid, pouring off the solution from the undissolved silex. The liquor is evaporated to dryness; the residuum being dissolved in water, the compound of nitric acid and yttria is obtained; ammonia is cautiously added; and after the separation of any oxide of iron in yellow flakes, a larger quantity is added, which precipitates the earth. The method followed by Klaproth, of separating the iron by precipitation, by succinate of soda, and precipitating the yttria, by carbonate of soda, will probably afford it more pure.

Yttria is thus obtained in the form of a white powder,



smooth and insipid ; it is heavier than any other earth, its specific gravity being 4.842. It is insoluble and infusible.

Yttria is not dissolved by the liquid alkalis ; nor do they redissolve it when added in excess, after having precipitated it from its solution, which distinguishes it from glucine. It is soluble in carbonate of ammonia, but it requires a quantity five or six times greater than glucine does. Prussiate of potash throws down from its solutions a granular precipitate of a white or pearl-grey colour. It is precipitated in grey flocculi by the infusion of galls. It is not affected by sulphuretted hydrogen.

Yttria combines with the acids : its salts have generally a sweetish taste. Several of them too are coloured, a property in which it differs from the other earths ; but, according to Eckberg, the colour arises from adhering metallic matter, principally manganese and iron. They are decomposed by the alkalis, by lime, strontites, and barytes.—CARBONATE OF YTTRIA is heavy, white and opaque.—NITRATE OF YTTRIA assumes a gelatinous consistence by evaporation ; its taste is sweet and astringent.—SULPHATE OF YTTRIA crystallizes in small brilliant grains, of a rhomboidal form, and of a colour inclining to amethyst red.—MURIATE OF YTTRIA assumes a gelatinous form.

The great specific gravity of this earth, and its being precipitated by the alkaline prussiates and by tannin from its solution, in some measure connect it with the metals, and it probably ought to be regarded as a metallic oxide. It is not reduced, however, to the metallic state by heating it with charcoal, but it runs with it into a kind of semi-fluid mass, which is heavier than the earth itself. When submitted to the action of potassium at a high temperature, some appearances indicate the production from it of metallic matter.



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A substance was announced in 1815 by Berzelius as a new earth, existing in gadolinite, to which he gave the name of THORINA. A farther examination of its nature has now proved that it is merely a sub-phosphate of yttria: the properties of the yttria are disguised by the acid, which is united to it with such force, that it could not be separated by any chemical agent. By means of the blowpipe, however, he was enabled to recognise the phosphoric acid and the yttria.

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## BOOK VI.

### OF METALS AND THEIR COMBINATIONS.

THE metals form a class of bodies of high importance from their chemical agencies, and not less so from the extent and variety of their applications in the useful arts. Some of them have been known from the remotest antiquity; by far the greater number have been discovered in modern times; and a considerable proportion even within the present century. The following table exhibits the dates of their discovery, and the names of the chemists by whom they were made known.



Names of Metals.	Date of Discovery.
Gold, .....	Known to the Ancients.
Silver, .....	
Copper, .....	
Tin, .....	
Iron, .....	
Lead, .....	Described by Basil Valentine, ... 15th century.
Mercury, ..	
Antimony, .....	
Bismuth, .....	
Zinc, .....	
Arsenic, .....	Known to Paracelsus, who died in 1541.
Cobalt, .....	
Brandt, .....	1733.
Platina, .....	Wood, Assay-Master, Jamaica, .. 1741.
Nickel, .....	Cronstedt, ..... 1751.
Manganese, ....	Gahn and Scheele, ..... 1774.
Tungsten, .....	Messrs D'Elhuyart, ..... 1781.
Tellurium, .....	Müller, ..... 1782.
Molybdenum, ..	Hielm, ..... 1782.
Uranium, .....	Klaproth, ... ..... 1789.
Titanium, .....	Gregor, ..... 1791.
Chrome, .....	Vauquelin, ..... 1797.
Columbium, ...	Hatchett, ..... 1802.
Palladium, .....	Dr Wollaston, ..... 1803.
Rhodium, .....	
Iridium, .....	Tennant and Descotils, ..... 1803.
Osmium, .....	Tennant, ..... 1803.
Cerium, .....	Hisinger and Berzelius, ..... 1804.
Cadmium, .....	Stromeyer, ..... 1817.
Selenium, .....	Berzelius, ..... 1818.

## METALLIC BASES OF THE ALKALIS AND EARTHS.

Potassium, .....	Sir H. Davy, ..... 1807.	
Sodium, .....		
Barium, .....		
Strontium, .....		
Calcium, .....	Arfwedson, ..... 1818.	
Lithium, .....		
Silicium, .....	Berzelius, ..... 1824.	
Zirconium, .....		

No class of bodies is better defined than that of Metals. Their peculiar lustre, perfect opacity, great density and tenacity, are properties which, to the same extent, belong to none of the other varieties of matter, and which, pos-



essed by each metal, serve to distinguish it without ambiguity.

Of the physical properties characteristic of the metals, that of *density* used to be regarded as the most distinctive. The specific gravity of fossil substances not metallic seldom exceeds 2 or 3, water being 1, and the heaviest of them is not more than 4.5, while the lightest of the metals exceeds 5; many of them are more than ten times heavier than water; and some from fifteen to twenty times the weight of that fluid. The bases, however, of the earths, and still more of the fixed alkalis, while they have all the other metallic qualities, have not that of density; and if they are to be regarded as metals, this furnishes a striking exception. But it is not certain, as has been already remarked, that these substances are pure metals; and it is not improbable that their levity may be owing to the presence of hydrogen.

The following Table exhibits the specific gravities of the true metals:

Platina, .....	20.98	Arsenic, .....	8.308
Gold, .....	19.36	Nickel, .....	8.279
Iridium, .....	18.68	Iron, .....	7.788
Tungsten, .....	17.6	Molybdenum, .....	7.4
Mercury, .....	13.5	Tin, .....	7.291
Palladium, .....	11.3 to 11.8	Zinc, .....	6.861 to 7.1
Lead, .....	11.352	Manganese, .....	6.850
Silver, .....	10.5	Antimony, .....	6.702
Bismuth, .....	9.822	Tellurium, .....	6.115
Uranium, .....	9	Titanium, .....	5.3
Copper, .....	8.8	Cerium, .....	4.489
Cadmium, .....	8.604	Selenium, .....	4.6
Cobalt, .....	8.58		

It may either be supposed, that the great specific gravities of the metals are owing to the great condensation and intimate union of their particles, or to the weights of their atoms or ultimate particles being considerable. Much, it is



conceived, is due to the latter circumstance ; for the combining weights of metals are higher than those of other simple bodies, and, in general, the combining weights of the heavier metals are greater than those of lighter metals. Thus gold is one of the heaviest of the metals, and its atomic weight is one of the largest. To this principle, however, there are many exceptions, which sufficiently prove that much also is to be attributed to the first cause, that of cohesion, in explaining the greater specific gravity of the substances of this class.

*Opacity* so far belongs to the metals, that when in the thinnest plates into which they can be reduced without the continuity being broken, they transmit no light, while the most opaque substance of any other class becomes translucent under a similar mechanical division. The only exception, perhaps, with regard to the metals, is afforded by gold, which, in very thin leaves, transmits a green light ; this, however, may perhaps be owing to fissures in it when reduced to such a state of tenuity.

The opacity of the metals, and the closeness of their texture, cause them to reflect the greater part of the light which falls on their surface : they hence possess a high degree of *lustre* or brilliancy. Many of them lose this from the tarnish they suffer from exposure to the air ; but in their fresh fracture they all exhibit it. It is increased also by the high polish of which they are in general susceptible.

The property of tenacity or strong cohesion of parts, appears in the metals under two forms, *ductility* and *malleability*. By the former is understood that modification of tenacity whence a body can be drawn into fine wire ; by the latter, that in consequence of which it can be beat or extended into thin leaves. Though both properties



are connected, they are still distinct, and are possessed in different degrees by different metals. Where hardness accompanies tenacity, its extension into leaves is difficult, while that into wire is easily executed; hence iron can be drawn into finer wire than any other metal, or possesses the greatest ductility, while it has little malleability. Platina has nearly the same character; Dr Wollaston has obtained wires of it of the extreme minuteness of  $\frac{1}{30000}$ th of an inch in diameter. In the soft metals, on the contrary, tenacity appears usually under the form of malleability. Thus gold, tin, and lead, can be extended in thin plates, without being capable of being drawn into very fine wire. Gold, indeed, in malleability, exceeds all known substances, as one grain of it may be extended so as to cover 52 square inches, forming a leaf not thicker than  $\frac{1}{282020}$ th of an inch. Silver and copper, being metals of medium hardness, have both properties, nearly perhaps in equal proportions. In a number of the metals, the brittleness is such as to prevent their extension to any great degree of fineness under either form. The extension of the metals is facilitated by a certain degree of temperature, this favouring their expansion, increasing the distances between their particles, and probably lessening their hardness or rigidity; but if heated beyond a certain temperature, brittleness is communicated, probably from the attraction of cohesion being weakened. Hence the metals are in general brittle when heated near to their melting point.

The degrees of tenacity of ductile metals may be ascertained by suspending weights to wires of these metals, and finding the greatest weights which they can support without breaking: the following were the weights which Morveau found to be thus sustained by wires of different metals, each  $0.0787$ th of an inch in thickness.



	Pounds.
Iron wire supported .....	549.25
Copper, .....	302.278
Platina, .....	274.32
Silver, .....	187.137
Gold, .....	150.753
Zinc, .....	109.54
Tin, .....	34.63
Lead, .....	27.621

The quality of *hardness* belongs to the metals, but is possessed by the different metals in very different degrees. In all of them it can be increased by artificial methods, principally by cooling them suddenly when they have been highly heated. The hardness acquired from this hasty approximation of the particles is accompanied with a corresponding degree of brittleness. The softness and tenacity can be restored by again heating them, and allowing them to cool slowly, a process which, when performed with this view, is termed *Tempering*.

In their relations to caloric, metals observe the same general laws as other bodies. They are superior to all others in conducting power; they also excel others in power of reflecting caloric, while they do not radiate so perfectly, nor absorb radiant heat with such facility. Their *fusibility* is very various. Quicksilver is so fusible as to require a reduction of temperature equal to  $-40^{\circ}$  to congeal it; while other metals, as molybdena, titanium, or platinum, can with the utmost difficulty be fused. In congealing, they so far assume a crystalline arrangement, as to exhibit an internal structure peculiar to each. Iron, for instance, has been shown by Mr Daniell to have a fibrous texture, bismuth and antimony a lamellar, and steel a granular texture. By melting, and then slowly cooling them, several of the metals can be made to assume regular



crystalline forms, generally those of the cube, octohedron, or tetrahedron. In *volatility* they are likewise extremely various. Quicksilver boils under a medium atmospheric pressure at a temperature a little below  $700^{\circ}$ . Arsenic is even more volatile, while the greater number require very intense heats to convert them into vapour.

Metals, in relation to electricity, conduct it better than any other bodies. They evolve it by mutual contact, whence their power of generating galvanism.

Metals exert numerous chemical affinities, and enter therefore into an extensive series of combinations. They unite with oxygen, with sulphur, chlorine, iodine, phosphorus, and carbon, and with each other; and when combined with oxygen, they farther combine with acids, and frequently with alkalis and earths. Of these combinations, that with oxygen is the most important, and a number of general facts have been established with regard to it.

The combination of a metal with oxygen in general takes place, when it is favoured by a sufficient elevation of temperature; and it is this which constitutes the important change which many metals suffer when heated under exposure to the air. The metal loses its lustre, scales form upon its surface, and as this proceeds, it is deprived of its tenacity, density, and other characteristic properties, and is converted into a powder, dull, and in general earthy in its appearance. This process was formerly named Calcination, and the product was denominated a Metallic Calx. It is merely the combination of the metal with oxygen, being thus analogous to the common process of combustion, and often indeed exhibiting the phenomena of that process.

The oxidation of a metal, by the agency of atmospheric air, takes place in different metals with different de-



degrees of facility. Some, as arsenic and manganese, suffer it with facility at common temperatures; others, as lead and copper, slowly, and not without the presence and operation of moisture. In general, it is necessary to raise the temperature considerably; and to many of them it is necessary to apply very intense heats. Some are oxidated at the temperature at which they melt; others, even when in perfect fusion, undergo no change; some are oxidated when the heat is raised sufficiently high to convert them into vapour; and others, as gold or platina, resist oxidation at either temperature, and can scarcely be made to undergo it from the action of oxygen in its elastic form. The application of heat, in promoting metallic oxidation, is to be explained on the same principles as its agency in favouring in general chemical combination. It acts by lessening the cohesion of the metal, which is an obstacle to the combination: this is counteracted, however, to a certain extent, by its necessarily augmenting the elasticity of the oxygen gas; and hence, where the mutual affinity between the metal and the oxygen is weak, the combination is not affected.

The phenomena which accompany the combination of a metal with oxygen are various. In general, it takes place slowly, and hence there is scarcely any sensible evolution of light, and no such extrication of caloric as to enable the combination to proceed independent of the continued application of heat. In some, however, the oxidation is so rapid as to give rise to the phenomena of combustion: thus zinc and iron burn vividly at a temperature a little higher than that of ignition; copper, tin, and arsenic, burn at the same temperature, with a more feeble flame; and at more intense heats, nearly all the metals suffer combustion.

The substances formed by the combination of oxygen



with metals are in general oxides. With regard to several of them, however, as arsenic, molybdenum, chrome, and perhaps tungsten, the oxidation can be carried so far as to produce compounds with distinct acid powers.

Metallic oxides have few common characteristic properties. They are usually of an earthy appearance, without the lustre, tenacity, or density of the metals. Several of them may be vitrified; they then form glasses more or less transparent, of dark colours. Their chemical relations are entirely different from those of the metals; they exert affinities to the acids, alkalis, and earths; and in their combinations with acids, neutralize the acid properties. In these properties they are analogous to the alkalis and earths; and in strictness of chemical arrangement, they probably form with these substances only one class. The common metallic oxides differ, however, from the alkalis and several of the earths, in being less soluble in water, whence they display less energy in chemical action.

In combining with oxygen, the metals unite with different proportions of it: the proportion, for example, in oxide of gold or silver, does not exceed 7 parts in 100, while in that of iron or manganese it exceeds 40. If the quantity condensed can be regarded as a measure of the force of affinity which the metal exerts, as Berthollet's views of chemical attraction suggest, we should have a correspondence apparently strict between this criterion and that which is afforded by the comparative facility and difficulty of decomposition; for of the above oxides, those of gold and silver are decomposed with great facility, while the entire decomposition of those of iron and manganese is extremely difficult.

Each metal, in combining with oxygen, combines with different proportions of it, and these combinations, in conformity to the usual law of chemical attraction, give rise



to compounds having very different properties. Quick-silver, with a small proportion of oxygen, forms an oxide of a grey colour; with a large proportion of oxygen, it forms one which is red; manganese forms a green and a black oxide, iron a black and a red; and there are others in which the degrees of oxidation are more numerous, marked by differences of properties sufficiently distinctive. The force with which the oxygen is retained in these combinations is different, being less strong as the proportion of oxygen is greater. Hence the partial decomposition of an oxide can often be easily effected, while the entire decomposition requires the introduction of a more powerful force.

The opinion is now fully established, that these combinations of a metal with oxygen take place in a few determinate proportions, and that between these proportions there are no intermediate combinations. Thus there is a black oxide of mercury, consisting of one equivalent of mercury, 200, and one of oxygen, 8; a red oxide of mercury, composed of one equivalent of mercury, 200, and two of oxygen, 16. There is a green oxide of manganese, containing 8 parts of oxygen to 28 of metal; a brown oxide, containing 12 parts of oxygen; and a black oxide, containing 16 parts of oxygen. And between these proportions, no direct combinations of the metals and oxygen exist. Proust carried this principle of definite combinations so far as to suppose, that with regard to every metal, there are only two determinate degrees of oxidation. Berthollet, on the contrary, maintained that the proportions may be indefinite between the *minimum* and the *maximum* of oxidation; that they generally are so; and that if in some cases determinate proportions are observed, this is owing to the operation of circumstances which limit the combination, and which in general being uni-



form, give rise to an invariable proportion. The opinion of Berthollet is now generally abandoned: indeed, the cases are so numerous of metals which combine in well-marked and definite proportions, and the analogy of other chemical combinations in which the law of definite proportions is observed is so strong, that the common doctrine is the only one that can be maintained. The supposition of Proust is, however, too limited; for there are many metals which form three, and some which form even four or five compounds with oxygen. Those oxidated products which, on Berthollet's view, were regarded as distinct oxides, are now considered as intermixtures of a few oxides of definite constitution.

The nomenclature by which the different oxides of each metal are denominated, is one extremely convenient, which was proposed by Dr Thomson. It is that of prefixing the Greek numerals to denote the degree of oxidation. Thus, an oxide which consists of one equivalent of the metal and one of oxygen, is termed the protoxide; that in which there are two equivalents of oxygen, the deutoxide; that in which there are three, the tritoxide or teroxide; and the oxide which contains the highest proportion of oxygen, the peroxide. Where there is only one compound it may be called simply the oxide. When, as in a few cases happens, two equivalents of metals are united with one of oxygen, the name of suboxide is given to the compound. In those instances where the metal acquires by oxidation acid powers, the name of the acid is simply derived from the metal: thus we have the Chromic and Arsenic acids. Oxides are frequently also distinguished by their colour: thus we have the black and red oxides of iron. The following table exhibits the composition of most of the metallic oxides:



METALS.	Metal.	Oxygen.	Equivalent of the oxide.	Colour of the oxide.
Gold, protoxide, .....	200	8	208	
peroxide or (teroxide,) .....		24	224	
Silver, oxide, .....	110	8	118	olive.
Platina, protoxide, .....	96	8	104	black.
deutoxide ? .....		12	108 ?	iron grey.
peroxide, .....		16	112	
Iridium, protoxide, .....	30	8	38 ?	blue.
		16	46 ?	red.
Rhodium, protoxide, .....	44	8	52	black.
peroxide, .....		16	60	yellow.
Palladium, oxide, .....	56	8	64	black.
Mercury, protoxide, .....	200	8	208	black.
peroxide, .....		16	216	red.
Copper, protoxide, .....	64	8	72	red.
peroxide, .....		16	80	black.
Iron, protoxide, (deutoxide ?) .....	28	8	36	black.
peroxide, .....		12	40	red.
Tin, protoxide, .....	58	8	66	grey.
peroxide, .....		16	74	white.
Lead, protoxide, .....	104	8	112	yellow.
deutoxide, .....		12	116	red.
peroxide, .....		16	120	brown.
Zinc, oxide, .....	34	8	42	white.
Bismuth, oxide, .....	72	8	80	yellowish.
Antimony, protoxide, .....	44	8	52	dull white.
deutoxide, .....		12	56	white.
peroxide, .....		16	60	yellow.
Arsenic, deutoxide, (acid ?) .....	38	16	54	white.
peroxide, (acid,) .....		24	62	do.
Cadmium, protoxide, .....	56	8	64	brownish-yellow.
Cobalt, protoxide, .....	26	8	34	blue.
peroxide, .....		12	38	black.
Nickel, protoxide, .....	26	8	34	ash-grey.
peroxide, .....		12	38	black.
Manganese, protoxide, .....	28	8	36	green.
deutoxide, .....		12	40	brown.
trioxide, .....		16	44	black.
Molybdenum, protoxide, .....	48	8	56	brown.
deutoxide, .....		16	64	blue.
peroxide, (acid,) .....		24	72	white.
Chrome, protoxide, .....	28	8	36	green.
deutoxide, .....		16	44	brown.
peroxide, (acid,) .....		24	52	red.
Tungsten, oxide, .....	126	16	142	black.
peroxide, (acid,) .....		24	150	yellow.
Tellurium, oxide, .....	32	8	40	yellowish.
Titanium, protoxide ? .....	32	8	40	blue.
peroxide, .....		16	48	white.
Uranium, protoxide, .....	208	8	216	green.
deutoxide, .....		16	224	yellow.
Columbium, oxide, (acid ?) .....	144	8	152	white.
Cerium, protoxide, .....	50	8	58	white.
peroxide, .....		12	62	fawn coloured.
Selenium, oxide, (gaseous,) .....	40	8	48	
peroxide, (acid,) .....		16	56	white.



Metallic oxides may be decomposed, by abstracting the oxygen, and the metal again obtained in its metallic state. This constitutes the process named Reduction, and it is effected in various modes.

The oxides of some metals are reduced to the metallic form by the operation of caloric alone : those of gold, silver, and quicksilver, are thus reduced by a heat not much superior to that of ignition ; and others, by elevation of temperature, suffer a partial reduction.

In general, however, it is necessary to introduce the agency of other substances exerting an affinity to oxygen. Charcoal is the one most powerful and most convenient in its operation ; and hence, the oxides of all the metals, when exposed to a heat sufficiently intense, in mixture with charcoal powder, or with matter capable of being converted into charcoal, as any vegetable substance, are reduced, the carbonaceous matter combining with the oxygen of the oxide, and forming carbonic acid, carbonic oxide, or portions of both, according to the proportions employed, or the force of affinity with which the oxygen is retained. The metal thus deprived of oxygen is at the same time fused. The addition of some substances favours the operation, by melting and thus communicating that state of fluidity favourable to chemical action, or by a resulting affinity aiding the formation of carbonic acid by the union of the carbon and oxygen. Carbonate of potash mixed with charcoal, under the form of what is named the *black flux*, prepared by calcining a mixture of one part of nitre with two of tartar, is generally used for this purpose in experiments on a small scale. In reduction performed on a large scale, lime is useful, partly by the same operation, and partly by contributing to the vitrification and removal of any earthy matter.

Metallic oxides may be reduced by the action of other



substances, exerting a strong attraction to oxygen, as, for example, by hydrogen. A stream of this gas passed over heated metallic oxides will unite with their oxygen, forming water, and the pure metals will be obtained. Even one metal, under certain circumstances, reduces the oxide of another. Light reduces them partially or entirely, and they are decomposed when placed in the galvanic circuit, from the different relations of oxygen, and of metallic matter, to the different galvanic poles.

Metals suffer oxidation by deflagration with nitre, and by the action of acids, and of water; and these actions, being more complicated than the combination with elastic oxygen, present some peculiar phenomena.

If a metal be exposed to a high temperature in mixture with nitre, the oxygen disengaged from the acid of the salt combines with the metal, and usually with such rapidity as to produce the phenomena of combustion or deflagration. With regard to several of them, however, a very high temperature is necessary for this; and those which have a weak attraction to oxygen, particularly gold, silver, and platina, suffer the change imperfectly. Those which are more susceptible of oxidation, are in general by this process oxidated to the *maximum*, and frequently the oxide exerts an affinity to the potash of the nitre, and combines with it. A similar oxidation of metals may be effected by the agency of the chlorate of potash; and mixtures of this salt with a number of the metals detonate from percussion, as has been already stated.

Those metals which have a strong attraction to oxygen abstract it from water. Some of them, as iron, do so at a low temperature. At a high temperature, this decomposition of water takes place more rapidly, as it does also at a low temperature, when promoted by the disposing affinity of an acid.



Acids are, of all the classes of chemical agents, those which act with greatest force in oxidating metals; the acid either directly imparting oxygen to the metal, or enabling the metal to acquire it from the decomposition of water, or sometimes by absorption from the atmospheric air. According as one or other of these effects is produced, the action of an acid on a metal is attended with peculiar phenomena. If the acid operate by directly affording oxygen, the action is attended with the evolution of the other constituent principle of the acid, either pure or partially oxidated: if it act by enabling the metal to attract oxygen from the water which is present, then the operation is accompanied with the disengagement of hydrogen gas. Nitric acid always directly imparts oxygen to metals: in consequence of this decomposition, nitric oxide, nitrous oxide, or nitrogen gas is disengaged; and from the weak affinity between its elements, this acid acts on all the metals, gold and platina excepted. Sulphuric acid scarcely suffers decomposition, unless the affinity of the metal to oxygen be aided by a high temperature; and hence, in its concentrated state, it does not act forcibly on metals in the cold; but when diluted, its action is powerful in oxidating the metal by the decomposition of the water. The action of muriatic acid is similar; and hence, those metals only are oxidated by it as well as by diluted sulphuric acid, which are capable, when aided by the resulting affinity of an acid, of decomposing water. The compound acid, the nitro-muriatic, appears to be more powerful than any single acid in oxidating metals.

The effect of an acid, in those cases in which it promotes the oxidation of a metal by the decomposition of water, is an example of what is named *Disposing or Resulting Affinity*, as has been already explained under the general doctrines of attraction; it depends on the united



force of attractions, which, but by their co-operation, would not be apparent,—the attraction of the metal to oxygen, of the acid to oxygen, and of the acid to the metal. These overcome the single affinity of the oxygen to hydrogen; hence the water is decomposed, and the metal, the oxygen of the water, and the acid, enter into one combination.

In a few cases, an acid promotes the oxidation of a metal, by enabling it to attract oxygen from the air. This kind of action is generally exerted by weak acids: thus acetic acid acts in this way on copper or lead.

The action of an acid on a metal is not limited merely to causing its oxidation: as the oxidation proceeds, the acid combines with the oxide, and it is this which constitutes the solution of metals in acids. No acid directly combines with a metal; the metal must always be oxidated: hence, if an acid act on a metal, it does so by first communicating to it oxygen, directly or indirectly, in the modes above explained, and at the same time it combines with the oxide as it is formed, forming exactly the same compound as when the oxide itself is acted on by the acid. If the compound of the oxide and acid is insoluble, or of sparing solubility, it is precipitated as the mutual action proceeds; but if it is soluble, it remains in solution in the water of the acid, generally retaining an excess of acid in the combination.

The base, therefore, in immediate union with the acid in all these combinations, is not the metal, but the metallic oxide. It produces neutralization of the acid when the combination is in the due proportions. These compounds are analogous to those formed by the combination of the alkalis and earths with the acids; they are many of them soluble in water, and crystallizable. Being thus of a saline nature, they have been denominated Metallic



Salts ; and the same nomenclature is applied to them as the other orders of compound salts ; those which contain sulphuric acid being named sulphates, those containing nitric acid, nitrates, and the same mode being followed with regard to the others. The species is named from the metal which is the ultimate base, as sulphate of iron, nitrate of copper, &c. In strictness of nomenclature, the name ought to be derived not from the metal, but the metallic oxide, as it is this which is the primary base, or is in immediate combination with the acid ; but the other method has, from its conciseness, been preferred.

Most metals being susceptible of different degrees of oxidation, it is obvious that the same metal may, with the same acid, form different compounds, according as it is more or less highly oxidated. This accordingly gives rise to striking differences in these combinations, and to a number of important facts with regard to them.

The difference in the properties of these compounds, from the different states of oxidation in which the metal exists combined with the acid, is apparent in many examples. Thus, the green sulphate of iron, in which the metal is in a low state of oxidation, is quite different in its properties from the red sulphate, in which the metal is more highly oxidated.

The facts with regard to the production of these compounds, and the state of oxidation in which they exist, admit of a certain degree of generalization, under which they may be best enumerated. The following are the most important : *1st*, When a metal is acted on by a diluted acid, or by one having not much energy of action, it is usually less highly oxidated than when acted on by one more powerful, or which, from facility of decomposition, affords oxygen more readily. *2d*, When the solution takes place in the cold, the degree of oxidation is less considerable



than when the mutual action is favoured by heat. 3d, The oxidation of the metal may at first be at the *minimum*, but it may pass to a higher degree, from exposure to the air, oxygen being absorbed; or a similar change may be produced from a farther decomposition of the acid in the combination, especially if heat is applied. 4th, The affinity of the metallic oxide to the acids changes as the oxidation varies, being in general strongest to protoxides, and becoming less strong as the degree of oxidation is greater: hence the peroxide of a metal may be insoluble in an acid in which the protoxide is readily soluble; hence, too, metallic solutions, from exposure to the air, and sometimes from exposure to heat, may suffer a partial decomposition, a portion of precipitate being thrown down; this consists of the metal in a higher state of oxidation, which, from being in this state, exerts a weaker affinity to the acid, and hence the whole of it cannot be retained in solution, but a portion of it is precipitated, retaining a little of the acid combined with it. To this also is it owing, that some metallic oxides in a high state of oxidation are insoluble in sulphuric or nitric acid, but are dissolved by sulphurous, nitrous, or muriatic acid; the latter acids abstracting a portion of the oxygen of the oxide, and, in conformity to this law, allowing the more powerful affinity to be exerted. Nevertheless, though the peroxides of metals form the least stable combinations with the acids, yet they unite with larger quantities of these acids than the protoxides; and this is one reason, why peroxides are partially precipitated from their solutions, that a larger quantity of acid would be necessary to saturate them. Lastly, From this greater affinity of protoxides than of peroxides to bases, one metallic oxide may precipitate another from its combination with an acid; the action of the one, at a low state of oxidation, being more



powerful than that of the other in a high state of oxidation.

Metallic oxides, either in high or low states of oxidation, unite with acids as the metals do with oxygen, in a few certain and definite proportions. Their nomenclature is constructed on the same principle as that of the oxides, the salt which contains the protoxide of a metal has the term *proto*, and that which contains the peroxide the term *per* prefixed to it; thus we have protosulphate and persulphate of iron. The salt of a deutoxide may, in like manner, be called a *deuto* salt, but this term is scarcely ever required. Frequently, also, salts are distinguished by their colour; thus, we speak of the green and brown sulphates of iron.

The metallic salts, like the other orders of compound salts, may exist with various proportions of their constituent principles. When these are united in one proportion, the state of neutralization is established; but besides this, combinations may be formed in which there is an excess of acid, or an excess of oxide. In the former case, the Latin preposition *super* is prefixed, in the latter, the preposition *sub* is employed. As it sometimes happens, that in the salt containing the larger proportion of acid the quantity of that ingredient is exactly double of what exists in the *sub* salt, the term *bi* is often used instead of *super* and *sub*: this is less frequently the case, however, than in alkaline and earthy salts. When, instead of two equivalents, as in bi-salts, there are two equivalents of base, Dr Thomson proposes to use the Greek syllable *dis* or *di* instead of *sub*; the latter, however, is the term commonly used. What are called *sesqui* salts, or those composed of an atom and a half of acid to an atom of base, are less unfrequent among metallic than among alkaline and earthy salts. To reconcile them with the doc-



trine of definite proportions, it may either be supposed, that salts exist with less proportions of acid which are yet undetected; or they may be regarded as compounds of two atoms of base and three of acid; or, lastly, as compounds of neutral salts with bisalts.

A highly important law with regard to the constitution of metallic salts in their neutral state has been established by the researches of Gay-Lussac,—that the quantity of acid necessary to saturate an oxide is directly proportional to the quantity of oxygen in the oxide. Hence a metal highly oxidated will require a large quantity of acid for its saturation, and *vice versa*. And the quantities of any acid combined with the oxides of different metals will be proportional to the quantities of oxygen with which these metals combine: so that if a metal combine with a proportion of oxygen equal to 5, and another metal combine with a proportion equal to 10, the quantity of acid necessary to saturate the latter will be, to that necessary to saturate the former, as 10 to 5. This law is deduced from the fact sufficiently established, that when a metallic salt is decomposed by a different metal, the latter attracts both the oxygen and the acid of the former, and the state of neutralization is always preserved: whatever quantity of oxygen therefore may be present, the quantity of acid is always such as to neutralize the oxide, and to be neutralized by it. It affords a method of determining the constitution of metallic salts: for if the proportions of oxygen in the oxides which are their bases be determined, we may discover by it the quantities of acid; and it may equally be applied to determine the composition of the oxides, as, if the quantities of acid be determined, we may infer the quantities of oxygen, the quantity of an oxide saturating the same weight of an acid containing the same quantity of oxygen. The law, in fact, is merely a case of



the general doctrine of definite proportions, and is hence strictly correct.

Metallic salts are in general more susceptible of decomposition than the other orders of compound salts. Many of them are decomposed by the action even of water, which exerting a stronger attraction to the acid than to the oxide, combines with it, and hence subverts the combination. In this case the decomposition is usually partial, the acid dissolved by the water retains a little of the oxide combined with it; the oxide which is precipitated retains a small portion of the acid in combination with it; and the neutral metallic salt is thus resolved into two compounds, one with an excess, the other with a deficiency of acid.

The action of an alkali, or of any of the soluble earths, on these metallic combinations, is similar, only more energetic. The alkali exerting a stronger attraction to the acid, abstracts a larger portion of it; but the oxide in its separation often retains a little of the acid in combination with it, and frequently the acid, in entering into union with the alkali, carries a small proportion of the oxide with it. The oxide which is precipitated generally retains less acid combined with it than when the decomposition is effected by water, and chemists were even accustomed to regard these precipitates as pure oxides; but, however powerful the action of the alkali may be, it is opposed, as the decomposition proceeds, by the increasing relative quantity of oxide to the remaining acid: hence the abstraction of the acid is seldom complete.

The alkali, in decomposing these salts, sometimes reacts on the oxide, and dissolves a portion of it, or when added in excess, forms with it and the acid a ternary combination. Ammonia has in particular this tendency, and sometimes too it has been supposed to decompose the oxide partially, its hydrogen attracting a portion of the oxygen, and reducing it more nearly to the metallic state.



There is one kind of decomposition peculiar to the metallic salts, that in which the oxygen is abstracted from the oxide, so that it is reduced to the metallic state. This is generally produced by one metal acting on the solutions of another ; thus if a slip of iron is immersed into a solution of a salt of copper, the surface of the iron is slightly corroded, and is covered with a film of metallic copper, so that the iron takes both the acid and oxygen from the copper, and is dissolved in its place : in like manner, copper precipitates silver or quicksilver from their solutions.

It was conceived, that in these cases the decompositions arise chiefly from the relative forces of affinity of the metals to oxygen ; the metal which is precipitated from any of its saline solutions, having a weaker affinity to oxygen than the metal which precipitates it ; hence it yields the oxygen to the former, becomes insoluble, and is separated in its metallic form, while the other, by its combination with oxygen, becomes capable of combining with the acid with which the oxide of the other had been united. A part of the effect is also due to the affinity of the precipitating to the precipitated metal. A proof of the influence of this latter circumstance is derived from the facts, that it is where such affinities exist between the metals that these precipitations occur most readily, and that the metal precipitated has generally a small portion of the other metal combined with it

If the precipitations in these decompositions take place slowly, the metal assumes somewhat of a crystalline arrangement, forming what has been named *Metallic Arborescence*, and the accretion of new matter has been observed to take place from the extremities of the filaments already formed. This phenomenon depends on galvanic action. When the precipitation of the dissolved metal



takes place on the surface of the metal by which the reduction is effected, this produces the usual galvanic combination of two metals in contact with an interposed liquid; the decomposition of the water of the liquid commences, its oxygen is attracted to the positive metallic surface, which, in conformity to the common law, is that of the metal having the strongest attraction to oxygen, and its hydrogen is attracted to the negative surface, which is the extremity of the reduced metal; the first metal is thus more quickly oxidated and dissolved, while the hydrogen operates in producing the farther reduction, by attracting the oxygen from the metal of the dissolved salt; and the particles of this metal thus reduced are deposited at that extremity, and extend the ramifications. Similar decompositions are produced by some inflammable substances, as by hydrogen, charcoal, and phosphorus, especially when their action is favoured by the chemical agency of light.

The alkalis exert scarcely any sensible action on the metals in their metallic state: they combine, however, with a number of the metallic oxides, dissolving them in the humid way, and, by the application of heat, forming compounds which are sometimes capable of being vitrified. Ammonia more particularly combines with them; its compounds are named Ammoniurets: some of them are very liable to decomposition, and suffer it even with explosion from heat or percussion. In these combinations the opposite law appears to be observed, from that which regulates the combination of the acids with the metallic oxides,—the affinity exerted by the alkali being more powerful to the oxide in a high than in a low state of oxidation, and these combinations being hence usually established in the former state. The solutions of certain metallic oxides in alkaline liquors may be decomposed, according to Klaproth, by the action of another metal attracting oxygen



from the one which had been dissolved, and precipitating it in its metallic form.

The metallic oxides exert an affinity to water, and hence, when formed by precipitation from metallic salts, they often retain a portion of water in combination, forming what are named Hydrates, or hydrated oxides. The quantity is frequently considerable, and modifies their properties, particularly their colour.

Chlorine exerts strong affinities to metals, and is capable of combining with every one of the class. Its action upon several of them is so rapid and violent as to exhibit all the phenomena of combustion, much heat being produced, and a considerable evolution of light. The compounds are called chlorides, and are distinguished like oxides by the terms of protochlorides, deutochlorides or bichlorides and perchlorides. Chlorine, it is conceived, has even a stronger attraction to metals than oxygen; for when metallic oxides are heated in it, oxygen is evolved, and chlorides remain. Chlorides may also be formed by heating various metals in muriatic acid gas, when hydrogen gas is at the same time separated. The chlorides are, with the exception of two, those of platina and gold, not decomposed by the application of any heat, unless hydrogen be present, when several of them are reduced to the metallic state, muriatic acid being formed. They are usually solid, except two of them, the bichlorides of tin and arsenic, which are liquid. They may be melted by heat, and in cooling assume a crystalline structure: several of them are very volatile, and sublime unchanged. They are frequently coloured, usually of an earthy appearance, and without metallic lustre, indeed, in most of their characters, they very much resemble dry salts. When thrown into water some of them continue chlorides, others are conceived to become muriates; but it cannot be said with certainty with what



chlorides this change happens. Insoluble chlorides are supposed to continue as such whether moist or dry. Berzelius extends the same supposition to the soluble chlorides; and though this is considered as an improbable doctrine, it has at least the merit of consistency, and of establishing a general analogy among the compounds of chlorine. The opinion generally received at present is, that soluble chlorides decompose water in the manner that has been repeatedly stated, and become muriates. A number of chemists, however, consider the chlorides of those metals which have little affinity to oxygen, as those of gold, silver, platina, mercury, &c., as chlorides even when moist or in solution; and with regard to those metals which have neither a very strong nor very weak attraction to oxygen, as copper, lead, cobalt, nickel, &c., their chlorides, when dissolved in water, may be regarded by the chemist either as chlorides or muriates as he chooses, the one opinion being entitled to as much confidence as the other. The metallic chlorides are, with the exception of those of gold and platina, not decomposed by heat, nor by charcoal though aided by heat, unless moisture is present. Hydrogen decomposes them, the metals appearing, and muriatic acid being formed.

Chlorine also unites with metallic oxides, the properties of which are neutralized; the principal of these compounds are those with oxides of zinc, copper, and iron. These combinations are not permanent.

Iodine exerts affinities to metals, and forms combinations with them similar to the compounds of chlorine. They are termed Iodides. Such of them as are soluble are generally supposed, as has been stated, to become hydriodates of metallic oxides when dissolved in water. The attraction of Iodine to metals seems to be weaker than that of oxygen or chlorine. Chlorine, it has been stated, ex-



pels oxygen from almost all oxides at high temperatures, and takes its place; but iodine expels oxygen from only a few oxides, and most of the iodides are themselves decomposed by exposure to oxygen gas at a red heat.

Hydrogen has affinities to several of the metals. It was known to be capable of retaining dissolved, in its elastic form, small portions of zinc, and perhaps of iron; and arsenic is dissolved by it in considerably larger quantity, forming a compound inflammable gas. It also appears, that it can form with several metals solid compounds. When tellurium is employed as the negative wire of the galvanic battery in the decomposition of water, the hydrogen gas usually evolved does not appear, but a brown powder falls down, which is a compound of the metal with hydrogen. A similar appearance may be obtained from arsenic; and tellurium, like arsenic, forms also with hydrogen gas an elastic compound. These solid compounds may be named *Metallic Hydrurets*.

Carbon unites with some of the metals, particularly with iron. Plumbago is a natural, and Steel an artificial compound of this kind. Carbon unites too with zinc: but not in any appreciable quantity, so far as has been ascertained, with any of the others.

Sulphur combines with all the metals by fusion, gold and zinc excepted; its combination with some of them being attended, as has already been remarked, with the evolution of heat and light, probably from a similar cause as that which gives rise to the same phenomena in the combination of oxygen with combustible bodies,—a diminution in the capacity for caloric, and a change in the chemical relation of the compound to the light existing as a constituent principle in one or both of the bodies combined. The effect has no connection with oxygenation, for it takes place when the metal and sulphur are heated



*in vacuo* ; and it is not promoted by the presence of a portion of oxygen, neither heat nor light being evolved, when the metal is employed in the experiment in the state of an oxide ; the compound, too, is found to be a pure sulphuret. Metallic sulphurets may also be formed by heating oxides with sulphur : the oxygen unites with a portion of sulphur and escapes in the state of sulphurous acid, and a sulphuret of the metal remains. They may also be obtained by the methods of Berthier and Berzelius, of heating sulphates of the metals with charcoal, or passing hydrogen gas over the sulphates at a red heat.

The compounds of the metals with sulphur have a lustre approaching to metallic ; they are opaque, hard, and brittle, generally more fusible than the metal of which they are composed, and insoluble in water. The sulphur usually combines with the metal in more than one proportion : these proportions are definite, and the larger are simple multiples of the smallest. The compounds in relation to each other are named sulphurets, or proto-sulphurets, sub-sulphurets, and bi-sulphurets, &c. according to the proportions. In the proto-sulphurets, the attraction by which the elements are combined is in general sufficiently strong to prevent the expulsion of the sulphur by heat ; on the other hand, the compounds containing an excess of sulphur frequently lose a part of it from a strong heat. All the sulphurets are decomposed by the joint action of heat and air. If the sulphate of the metal is capable of sustaining a red heat, it is formed ; but if it would be decomposed at such a temperature, the oxygen of the air unites with sulphur, forming sulphurous acid, which escapes, and a metallic oxide is left, or sometimes the reduced metal only remains. If sulphurets are moistened and exposed to the air, most of them, in no long time, absorb sufficient oxygen to become sulphates of oxides.



A law of considerable importance has been stated by Berzelius, with regard to the constitution of the metallic sulphurets,—that the proportion of sulphur to the metal is such, that when oxygen is communicated to the compound, so as to oxidate the metal, and convert the sulphur into sulphuric acid, a neutral compound is formed; the same quantity of sulphur, therefore, that exists in a metallic sulphate, exists in the sulphuret of the same metal. This law obviously follows from the doctrine of definite proportions.

Sulphur combines not only with the metals, but also with their oxides: the principal of these are the sulphuretted oxides of zinc, mercury and manganese; they are decomposed by acids evolving sulphuretted hydrogen gas. The attraction of sulphur to oxides is, however, much weaker than it is to the metals, and it becomes weaker as the degree of oxidation is greater.

Sulphuretted hydrogen displays relations to the metals somewhat similar. Its action is shewn by the tarnish it immediately communicates to their surface. It unites too with the metallic oxides, and from its attraction to them is capable of decomposing a number of the metallic salts. The precipitates which it forms from these are commonly hydrosulphurets of the metallic oxides. Not unfrequently a more complicated action is exerted, and metallic sulphurets are produced; the hydrogen of the sulphuretted hydrogen attracting partially, or entirely, the oxygen of the metallic oxide, while the sulphur combines with the metal, reduced to the metallic state. As these precipitates are usually of dark shades of colour, sulphuretted hydrogen is the most delicate test of metallic matter. It is applied sometimes under the form of its watery solution; there are some salts, however, particularly those to the oxides of which sulphur has no strong attraction,



which sulphuretted hydrogen alone cannot decompose. With regard to these, the presence of an alkali is necessary to saturate the acid, to admit of the formation of a precipitate; and hence the alkaline hydro-sulphurets, or sulphuretted hydro-sulphurets, are more active tests. They not only serve, too, to discover the presence of metallic matter in general, but to detect the different metals by the various colours of the precipitates which they form. According to Gay-Lussac, in these precipitations, the quantity of sulphuretted hydrogen which disappears is equivalent to the quantity of oxygen in the oxide. The hydro-sulphurets of oxides are not permanent compounds; the hydrogen of the acid, and the oxygen of the oxide in time unite, forming water, and a metallic sulphuret remains.

A singular action, not yet well understood, is exerted on some metals by sulphur in combination with an alkali. The compound enters into combination by fusion with the metal, and even with those metals with which sulphur alone does not combine, as with gold; and what is still more singular, the metal is thus rendered soluble in water. The former effect appears to be owing to the alkali preventing the volatilization of the sulphur, and thus allowing a higher degree of heat to be applied, to favour its combination, than can be applied when the sulphur and metal alone are heated: the combination, too, being perhaps favoured by the affinity which may be exerted by the metallic base of the alkali. The second effect is more difficult of explanation, nor is the nature of the compound obtained in solution in the water well determined: it is uncertain whether the metal is oxidated, and whether sulphuretted hydrogen exists in the combination.

Phosphorus has relations to the metals similar, under a general point of view, to those of sulphur. From its vo-



latility and inflammability, it cannot easily be directly combined with them, but the combination is obtained by exposing to heat a mixture of the metal with phosphoric acid and charcoal; the charcoal attracting the oxygen of the acid, and the phosphorus, as it is produced, combining with the metal. The metallic phosphurets have a degree of lustre approaching to metallic; they are usually soft, and are fusible and inflammable. As they are of very little importance, the individual phosphurets will seldom require notice.

The metals enter into combination with each other by fusion. These compounds are named Alloys: those with quicksilver, being soft or fluid, are named Amalgams. They have uniformly the metallic properties, opacity, lustre, density, &c. and generally, to a certain extent, the qualities of the metals of which they are composed, though these are also liable to be modified by the combination; and this modification extends not only to the physical qualities, which may be supposed liable to be altered by changes of arrangement in the particles composing the mass, but frequently also to the chemical qualities. The fusibility and volatility are different from the mean of those properties as possessed by the elements of the alloy; and what is still more important, the usual chemical relations are changed, so that re-agents which have a peculiar relation to a metal, either do not act on it, or act differently when it is in combination with another metal.

These combinations are not unlimited, either with regard to the metals which combine, or the proportions in which the combination is established. Some metals combine with great facility; others do not unite, as iron and lead, or iron and quicksilver. Frequently three or more metals can be brought into one combination. The facility of combining appears to be in some measure regulated by



an agreement in fusibility and specific gravity, so that when the mutual affinity is weak, a considerable difference between two metals in these properties will prevent their combination. The same properties regulate to a certain extent the proportions in which they combine. These, in many of these combinations, are unlimited. But frequently they are definite: thus the arbor Dianæ is a compound of silver and mercury in definite proportions. Indeed, wherever, by crystallization, or in any other mode, the alloy separates from the mass, it will be found to be of determinate constitution. The influence of specific gravity is found to operate in some combinations: thus, when an alloy of gold, or any heavy metal, is formed by fusion, and allowed to cool slowly, the upper and under parts of the mass are composed of the respective metals which form it, in different proportions, the under part containing more of the heavier metal, while the lighter predominates in the portion above. The combination of metals is usually attended with a degree of condensation, though in some cases the reverse happens, there being an enlargement of volume, probably from the crystalline arrangement which the particles of the compound mass assume.

The arts of gilding, silvering, and tinning, and the operation of soldering, depend on the mutual affinities which metals exert.

The metals form no combinations with the earths. The metallic oxides and the earths frequently combine by fusion, and form in general coloured glasses.

The metals are found in nature, either *native*, that is, in the metallic form, or in the state of *ore* or *mineralized*, that is, combined with some other substance, by which the metallic properties are disguised. The substances with which they are most frequently combined are, sulphur, oxygen, chlorine, and, according to Vauquelin, iodine, and various acids, particularly the carbonic, sul-



phuric, and phosphoric. These ores occur frequently crystallized, sometimes massive; they form, in a few cases, entire beds; more usually they are distributed in mineral veins, and are associated in these with various earthy fossils, particularly quartz, calcareous spar, sulphate of barytes, and fluor spar. When removed from their original repository, and freed, by pounding and washing, from the stony matter intermixed with them, they are subjected to calcination, fusion in contact with the fuel, and other operations variously adapted to particular ores, by which the foreign substances are separated, and the metal is reduced, and obtained sufficiently pure.

The number of metals, it has been stated, is about twenty-nine, or, including the bases of the alkalis and earths, 41, seven of which only were known to the ancients. The class has been subdivided into orders, under which the individual metals have been arranged. There is no advantage in such subdivisions, which are all either inconvenient or imperfectly defined; and the different metals may be considered in that order in which the transitions are most easy, so as to admit of those being associated which are most strictly connected. Those of recent discovery, and which are imperfectly investigated, may be placed together, and considered after the others; and with regard to some of these, the suspicion is probably well founded, that they are alloys of known metals, though these have not yet been detected in them.

The atomic weights of the metals, and of their principal salts, will be stated under their history, and will be found in the general table of combining weights at the end of the volume, as most of them are of too little importance to require separate tables. A number of their salts, such as most of the borates, phosphites, sulphites, fluates, &c. possessing no striking characters, and being applied to no use, need scarcely to be noticed in an elementary work.



## CHAP. I.—OF GOLD.

GOLD has always been placed at the head of the class of metals, and esteemed of the greatest value ; a superiority derived from the richness of its colour and lustre, which are not altered or tarnished by exposure to air or humidity, from its high ductility and malleability, and its indestructibility by many of the operations by which the other metals are disguised or changed. It is found usually native, and nearly pure ; sometimes, however, in combination with other metals, under the form of alloys, in which its characteristic properties are nearly concealed. It has been supposed to exist, too, in the vegetable kingdom, a minute quantity of it, according to the experiments of Rouelle, being capable of being extracted from the ashes of plants.

Native gold, when loosely interspersed or diffused, is freed from the foreign substances with which it is mixed, by washing it in a stream of water, on an inclined plane. The metallic residuum is triturated with quicksilver, until all the particles of gold are dissolved : the mercury is distilled off in iron retorts, and the gold remains, and is fused. When it is contained in other ores, the ore is roasted, to expel the volatile principles, and oxidate other metals that may be present, and the remaining gold is extracted by amalgamation with quicksilver, or fusion with lead. It still, as obtained by any of these methods, requires to be farther purified. This is done by the process termed Cupellation, which consists in combining the gold with a quantity of lead, and exposing the alloy to a melting heat, in a vessel termed a Cupel, formed of bone ashes and extremely porous, or in the large way, on the hearth of the



refining furnace. The lead is extremely susceptible of oxidation, and at the same time it promotes the oxidation of other metals, and vitrifies with their oxides. They are thus removed ; the vitrified matter is absorbed by the vessel, or is driven off by the blast of bellows as it collects on the surface, and the gold at length remains nearly pure. It can contain only silver, which is separated by the solvent power of nitric acid, forming the operation termed *Quartation*, or *Parting*.

Gold, when pure, is of a rich yellow colour, and its lustre is not impaired by exposure to the air or moisture ; its specific gravity is from 19.2 to 19.36 ; it exceeds therefore in density every metal, platina excepted ; its hardness is not considerable, but its tenacity, under the forms both of ductility and malleability, is extremely great : it can be drawn into very fine wire, not exceeding even 1-5000th part of an inch in thickness ; in malleability it is superior to every metal ; one grain of it may be made to cover a space of 56 square inches, and in the gilding of silver wire it has been calculated to be extended 12 times more than this.

Gold melts at 32 of Wedgwood's pyrometer, and by an intense heat, as that of a powerful burning mirror, is volatilized unchanged. It was supposed to be incapable of oxidation from atmospheric air or oxygen gas, at any temperature, as it had often been exposed to long continued intense heats, with the admission of the air, without suffering any change. It is now, however, sufficiently established, that an intense heat suddenly and momentarily applied causes its oxidation. This effect is produced by an electric discharge transmitted over gold leaf inclosed between plates of glass, or through a fine gold wire inclosed in a glass tube with atmospheric air. Gold can even be made to burn by powerful electric sparks ; it exhibits a vivid combustion in the galvanic circuit ; it burns also in the



flame of an united stream of oxygen and hydrogen. Lastly, it suffers the same change to a certain extent by being heated with nitre, as has been established by the experiments of Mr Tennant, contrary to an opinion which had been generally received, that it suffers no change from the action of nitre. The oxide of gold is of a purple colour; it is supposed to be at the *minimum* of oxidation, and to contain 4 parts of oxygen in 100; or assuming 200 as the atomic weight of gold, as calculated by Dr Thomson, the protoxide will consist of one atom of gold, 200, and one of oxygen, 8; hence its equivalent is 208. Besides this, another oxide of gold may be procured from some of its saline combinations, particularly from the muriate of gold and soda; which contains, according to Berzelius and Thomson, three equivalents; or it is a teroxide; its equivalent is therefore 224. Pelletier has regarded it as an acid, and termed it *Auric Acid*, and its solution in liquid potash he calls *Aurate* of potash. This is an opinion for which there seems to be very little foundation.

Gold is scarcely acted on by any of the acids. Even the nitric acid, which imparts oxygen so readily to the other metals, has scarcely any sensible effect upon it; and it is only when the acid is surcharged with nitric oxide, and boiled on the gold, that a very minute quantity is dissolved. Nor do any of the acids except the nitric and sulphuric dissolve even the oxide of gold. Chlorine and nitro-muriatic acid are the proper solvents of this metal. A solution of chlorine will dissolve gold leaf; and if gold leaf be introduced into chlorine gas, it immediately takes fire and burns. But the nitro-muriatic acid, composed usually, as has been stated, of two parts of nitric acid and one of muriatic acid, dissolves gold with much more rapidity; and hence has been long used for this purpose, under the name of *Aqua Regia*. Vauquelin has given the



proportion of two parts of muriatic acid, and one of nitric, as best adapted to the solution. It has been supposed, that the action of this acid is owing merely to the chlorine which it contains, and that it dissolves the gold by converting it into a chloride. But in this way the nitric acid can be of no use, and a solution of chlorine ought to be as rapid in dissolving gold as the aqua regia, while it is well known that solution of chlorine is much inferior in solvent power. A much more probable view is, that the muriatic acid, by a resulting affinity, enables the gold to decompose the nitric acid, and receive oxygen from it; the effect being analogous to that of muriatic or sulphuric acid dissolving a metal by enabling it to decompose water.

The solution of gold in nitro-muriatic acid, when concentrated, is of a rich yellow colour; it contains always an excess of acid, but by evaporation a salt is obtained, approaching to the neutral state, in small pyramidal crystals of the same colour. This salt is often regarded as a real chloride, or rather bi-chloride of gold; but as it always contains water, it may be with equal certainty considered as a muriate of oxide of gold; it is deliquescent, soluble in water, and in alcohol and ether; it is decomposed by heat, and by light.

The solution of gold in nitro-muriatic acid is decomposed by the alkalis. Potash and soda throw down a precipitate of a yellow colour, which is a hydrated oxide of gold containing a little chlorine: this renders it probable that oxide of gold exists in the solution, as it is more probable that it should be formed in its solution by the agency of the nitric acid, than that a substance, having so slight an affinity to oxygen, should, in the moment of precipitation, take oxygen from potassium or sodium, which have so strong an attraction to oxygen. By an ex-



cess of alkali it is in part re-dissolved. According to Vauquelin, the precipitation does not take place in the cold, but only at a boiling heat; it is also only partial; and it is farther diminished, if the alkali be in excess.

When solution of muriate of potash or of soda is added in proper proportions to the solution of muriate of gold, and the mixture evaporated, triple muriates of gold and potash, or of gold and soda, are obtained. The latter crystallizes in long four-sided prisms of a rich orange colour, which are not altered by exposure to the air. According to Dr Thomson, it consists of two atoms of muriatic acid, one of oxide of gold, one atom of muriate of soda, and five of water. Notwithstanding the presence of water in it, it is regarded by some as a compound of bi-chloride of gold and chloride of sodium, with eight atoms of water. Ammonia exerts a more peculiar action on solution of gold: it forms a precipitate, which, if an excess of alkali is added, is re-dissolved. This precipitate is highly fulminating, and has been known by the name of *Aurum fulminans*, fulminating or detonating gold. When dry, it explodes from the application of a heat not higher than  $300^{\circ}$ , or from friction or percussion; and as a very slight degree of friction causes it to detonate, it is necessary to make experiments on it with caution; the explosion is accompanied with an acute report, and a flash of light visible in the dark, and with a considerable exertion of expansive force. It has been ascertained by experiments made with caution on small quantities of it, that in its detonation nitrogen gas is disengaged with watery vapour, metallic gold intermixed with the purple oxide remaining: if heated very gently, so as to decompose it without detonation, ammonia is exhaled: the precipitate, therefore, is a compound of ammonia and oxide of gold, and its detonation is apparently owing to the re-action of the elements of



these, the oxygen of the oxide combining with the hydrogen of the ammonia, and forming watery vapour, the nitrogen of the ammonia escaping from the combination, and the elasticity of both being augmented by the extrication of caloric, which probably attends these new combinations.

Gold having a weak affinity to oxygen and to chlorine, its solution is easily decomposed. Thus, the chloride or muriate of gold is reduced by exposure to light, and by the agency of hydrogen, charcoal, and other inflammables. It is also decomposed partially or entirely by other metals; zinc, iron, and copper, throw down the gold in its metallic state; others precipitate it in the state of the purple oxide. Even some metallic salts, when at the *minimum* of oxidation, occasion similar decompositions. A solution of green sulphate of iron reduces the gold entirely to the metallic state, from its power of attracting oxygen, and is the re-agent by which gold is most completely precipitated from its solutions. A solution of tin in nitro-muriatic acid, prepared so as to be in a low state of oxidation, throws down a purple precipitate: this is a compound of the oxides of the two metals. Metallic tin immersed in the solution of gold has a similar effect. This precipitate has been long used, under the name of *Purple powder of Cassius*, to give a red colour to ornamental glass.

Another decomposition, rather singular, which solution of muriate of gold suffers, is that from the action of essential oils, alcohol, or ether. If a portion of essential oil be mixed with its solution, the watery portion is separated, the muriate of gold combines with the oil, and this combination can be dissolved in alcohol, forming a preparation known by the name of Potable Gold, which, from its comparative mildness, has sometimes been taken internal-



ly, when gold was supposed to possess medicinal powers. From these solutions the gold is gradually precipitated in its metallic state, the oxygen of the oxide being attracted by the hydrogen of the essential oil.

Gold may be combined with iodine, by mixing solution of gold with hydriodate of potash, and drying the precipitate. The iodide of gold is insoluble, is decomposed by acids, by alkalies and by heat. Its composition is not fully determined.

Gold does not combine with sulphur by fusion, but if melted with an alkaline sulphuret, as sulphuret of potash, a combination is formed, as has already been remarked, which is soluble in water. The alkaline hydro-sulphurets, and sulphuretted hydrogen, also throw down a precipitate from the solution of muriate of gold, which, according to Oberkampft, is a sulphuret composed of 100 of gold and 24 of sulphur. Gold unites with a small portion of phosphorus; the compound is white and brittle, is fusible, and easily decomposed by heat.

With the greater number of the metals gold forms alloys; those of them which are of any importance will be noticed under the history of the metals from which they are formed. In general, in these combinations, either its ductility or colour is much impaired. Copper and silver are those which change it least; and as copper renders it harder, this alloy is used for many of the purposes to which gold is applied, such as the fabrication of coin and ornamental vessels or trinkets. The standard gold of this country has an alloy of copper of one part in twelve. Lead, bismuth, and antimony, in very minute quantity, render gold quite brittle, so that even the vapour arising from these metals in fusion, coming in contact with melted gold, has this effect. Quicksilver too renders it brit-



tle, penetrates it rapidly, and, when in sufficient quantity, dissolves it.

Gold, as the most valuable of the metals, is employed as the medium of exchange, which regulates the value of the others. It is used for many ornamental purposes under different forms. There are various modes, too, of covering the surfaces of bodies with it for similar purposes. The gilding of metals is performed in the most substantial mode, by applying an amalgam of gold to the metal designed to be gilt, generally silver or copper, its surface being previously cleansed and brushed over with a dilute solution of quicksilver in nitric acid, so that a thin film of quicksilver shall be deposited on it, which favours the adherence and union of the amalgam. The quicksilver is volatilized by the application of a slow and equal heat, and the gold remains, covering the surface. Other kinds of gilding on metals, less substantial, are executed by rubbing the gold in a state of extreme mechanical division, on the surface of the metal heated, or by applying a solution of muriate of gold. Steel is gilt by dipping it in a solution of muriate of gold in ether or alcohol. Gold leaf is applied to wood, paper, &c. by an adhesive paste: and glass and porcelain are gilded by applying gold by the medium of borax, which vitrifies with a moderate heat.

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#### CHAP. II.—OF SILVER.

SILVER is a metal, which, like gold, is rendered valuable by its colour and lustre, its ductility and malleability, and not being liable to oxidation from exposure to the air. It is liable, however, to tarnish, by which the beauty of its



colour and its lustre are diminished, a change owing to the operation of minute quantities of sulphuretted hydrogen diffused through the atmosphere from animal effluvia. Its comparative scarcity has added to its value, and rendered it in the medium of exchange next to gold.

Silver is found native, and also mineralized by oxygen, chlorine, sulphur, muriatic and sulphuric acids, forming, in various states of combination and mixture, a number of ores. Native silver is extracted from the earthy matter mixed with it by amalgamation with quicksilver, which is afterwards abstracted by distillation. Its ores are subjected to various processes, principally roasting, and fusion in contact with the fuel. The metallic matter obtained is melted with lead, and refined by the process of cupellation, as has been described under the history of gold.

Silver has a colour approaching more nearly to pure white than any other metal; its lustre is considerable, and it is peculiarly sonorous, giving, when struck, a very clear sound. In malleability it is inferior only to gold; in ductility it is equal, or nearly so, to that metal: it is harder and more elastic; its specific gravity is 10.5. Silver melts at  $22^{\circ}$  of Wedgwood's scale; by slow cooling it is crystallized in octahedrons: it expands in becoming solid. By a powerful heat, it is volatilized. Its equivalent appears to be 110.

Silver was supposed to suffer no change from the action of atmospheric air at a high temperature. The practicability of its oxidation, however, has been sufficiently established. An electric discharge transmitted over silver leaf, or silver wire, by the high temperature it suddenly excites, causes the formation of vitrified oxide; in the circuit of a powerful galvanic battery, silver leaf burns with splendour; and its oxidation with the phenomena of



combustion is effected, by subjecting it to the intense heat excited by a stream of oxygen gas directed on burning charcoal, or mingled with hydrogen gas kindled; an oxide of an olive colour is obtained by these processes. This may be obtained also by precipitation from its solution in nitric acid. It consists of one atom of silver, 110, and one of oxygen 8, and its equivalent is therefore 118. It is reduced to the metallic state by an elevated temperature. According to Dr Thomson, and Mr Faraday, a *suboxide* of silver forms in a black pellicle on the surface of an ammoniacal solution of silver; it contains 3 atoms of oxygen to 2 of silver; it does not form salts.

Silver is oxidated by several of the acids, which at the same time combine with its oxide. Nitric acid is its proper solvent; in effecting its solution, the singular phenomenon is displayed which the same acid exhibits with regard to some other metals, and of which no satisfactory explanation has been yet given,—that when concentrated it has no sensible effect on the metal, while the addition of a very small quantity of water causes the action instantly to commence, whence the oxidation and solution of the metal proceed. The solution of silver in diluted nitric acid has at first a greenish colour: but if the silver has been pure, and in particular free from copper, (which, according to Dr Thomson, it very seldom is,) this arising merely from the presence of a little nitric oxide, soon disappears, and the solution becomes colourless: by evaporation, it affords white tabular crystals. This salt is abundantly soluble in water; it stains animal substances of a deep black; it also acts as a caustic very rapidly on animal matter; fused and run into cylindrical moulds, it forms the *lunar caustic* of surgeons, which is in common use as an escharotic, powerful in its action, and easily ap-



plied and regulated, in particular not being liable to deliquesce and spread like fused potash. Both the crystals and the fused salt are anhydrous, consisting of one atom of oxide of silver, 118, and one of nitric acid, 54, = 172. It is partially decomposed by heat, and likewise by light; it detonates when heated with combustible bodies, and with some of them, as phosphorus, it detonates on percussion.

The other salts of silver are obtained more easily by adding to the solution of nitrate of silver a solution of a neutral salt, containing the acid with which the oxide of silver is to be combined: thus the sulphate is formed by adding a solution of sulphate of potash or soda. It is also formed by boiling sulphuric acid on silver, the acid being decomposed at this temperature, communicating oxygen to it, and combining with the oxide. The sulphate of silver is very sparingly soluble in water; by boiling water upon it, a minute quantity is dissolved, and slender crystals are obtained by cooling. A mixture of sulphuric and nitric acids is found to be a useful solvent of silver, as it leaves undissolved any copper, gold, lead, or iron, with which the silver may be alloyed; it is prepared by dissolving 1 part of nitre in 8 of strong sulphuric acid: the silver is recovered from the solution by adding common salt, and decomposing the chloride of silver by carbonate of soda.

Muriate of silver, it is commonly supposed, on the new doctrine, does not exist; being insoluble, it is conceived to remain always as a chloride. This opinion does not, however, appear to be correct, as Mr Faraday states, that muriatic acid dissolves a small quantity of silver very readily, which is precipitated, as chloride of silver, by the addition of water. Chloride of silver may be procured by heating silver in chlorine gas, but is more easily obtain-



ed by adding a solution of muriate of soda to a solution of nitrate of silver, when it immediately falls down in the state of a white precipitate with a slight tinge of blue. From the extreme insolubility of this chloride, it is the re-agent of greatest delicacy in detecting the presence of muriatic acid; hence the importance of the determination of its composition. From the most accurate experiments, it appears to consist of 75.34 of silver, and 24.65 of chlorine, or of one atom of silver, 110, and one of chlorine, 36, = 146. Chloride of silver affords also the most delicate test of the chemical agency of light, being blackened by exposure for a few minutes to the rays of the sun. It is very fusible, melting on the application of a moderate heat in a glass matrass; on becoming solid, it retains a degree of transparency, is of a pearly colour, is soft, and to a certain extent malleable and fusible; whence, from its resemblance in these properties to horn, it received from the older chemists the name of *Luna Cornea*, or *Horn Silver*. By exposing it to a strong heat, it is decomposed; chlorine is expelled, and the silver is recovered in its metallic form. The decomposition is favoured by the presence of a small portion of alkali; one part of the carbonate of potash is added to four parts of the chloride, and the mixture is exposed to a red heat in a crucible, or rather in a phial within a crucible, surrounded with sand: this affords the best process for obtaining pure silver; 100 grains afford 75 of the metal. Iodide of silver is obtained by adding hydriodic acid to solution of nitrate of silver: it is an insoluble greenish precipitate.

Chlorate of silver can be formed, by transmitting a current of chlorine gas through water in which oxide of silver is diffused: its salt is soluble in water, and crystallizes in rhombs; it is also soluble in alcohol.

Phosphate of silver is insoluble in water, and is hence



precipitated when a solution of phosphate of soda is added to a solution of nitrate of silver.

The salts of silver are decomposed by the alkalis and earths. From nitrate of silver, potash throws down a yellowish precipitate, probably a sub-nitrate. The precipitate by ammonia is grey or black; it has not, like the precipitate from the solution of gold by ammonia, any detonating power.

A fulminating silver can be prepared, however, which far exceeds fulminating gold in power. The process was given by Berthollet; it consists in dissolving silver in nitrous acid, diluted with three parts of water: to the solution, lime-water is added as long as any precipitation is occasioned; the precipitate is washed and dried; it is then allowed to remain for several hours in liquid ammonia, when it becomes a black powder; the liquor is poured off from it, and it is allowed to dry in the air. This is the fulminating silver; such is its tendency to explosion, that it cannot be touched, the slightest agitation causing it to detonate; and so violent is the detonation, that the experiment cannot be made with safety on more than a grain. The theory of its detonation is considered as similar to that of fulminating gold: it probably consists of oxide of silver and ammonia, the elements being united by affinities so nicely balanced, that the slightest external force subverts them, and causes new combinations: the oxygen of the oxide unites with the hydrogen of the ammonia, and forms watery vapour: the nitrogen must assume the elastic form, and the augmentation of elasticity in these products, by the caloric suddenly extricated, may be the cause of the violence of the detonation. The superiority of this preparation in detonating power to fulminating gold, may be owing to the oxide of silver containing a larger proportion of oxygen, and com-



binning with a larger quantity of ammonia, so that there are condensed in the fulminating silver, a larger quantity of the elements disposed to enter into the combinations whence these elastic products are evolved.

Another fulminating silver is prepared by dissolving silver in heated nitric acid, and adding alcohol during the solution; or in the method of Liebeg, of dissolving a drachm of silver in half an ounce of nitric acid, of specific gravity 1.52, adding two ounces of alcohol, of specific gravity 0.85, and heating the mixture till it boils, and white crystalline flocculi are deposited. These detonate on the slightest friction, even when under water. Liebeg conceives that a peculiar acid exists in this fulminating silver, to which, as the cause of its explosive power, he has given the name of *fulminic acid*. The principal ingredients of it are supposed to be two atoms of carbon, one of nitrogen, and one of oxygen; or it may be considered, like the cyanic acid to be afterwards described, as a compound, of one equivalent of cyanogen, and one of oxygen. But it is also imagined, that a metallic ingredient is likewise essential to the existence of this acid, this additional element varying with the metal from which the fulminating compound is prepared; thus it may be silver, mercury, copper, zinc, or iron. The fulminic acid from the present compound contains silver therefore as an element, and is combined with oxide of silver: it may be separated by the alkalis and the earths: *fulminates* of these bases are formed, which can be obtained crystallized, and are all detonating compounds. The fulminate of potash is procured most easily by adding muriate of potash to the fulminate of silver. Sulphuretted hydrogen and muriatic acid decompose this acid, and it is imagined that other new acids are formed.

The salts of silver are decomposed by inflammable sub-



stances, hydrogen, phosphorus, and charcoal, and by the greater number of the metals, the oxygen being attracted from the oxide, and the silver precipitated in the metallic form. Among the metals, copper and quicksilver produce this precipitation with great facility, probably from the affinity exerted between the precipitating and the precipitated metal. Copper is employed to recover silver from its solution in nitric acid, as a mode of obtaining it free from other metals, the small quantity of copper with which the precipitated silver may be alloyed being removed by cupellation. Quicksilver employed in a peculiar manner in the precipitation of silver, causes its crystalline arrangement, similar in appearance to arborescence, hence forming what has been named *Arbor Dianæ*. The mode said to succeed best is to dissolve with the silver half its weight of quicksilver in nitric acid, and to drop into this solution, diluted with forty-eight parts of water, a small piece of a soft amalgam of silver: filaments of reduced silver soon shoot out from the amalgam, which take the form of a shrub, an effect probably in part produced by galvanic action.

Silver combines by fusion with sulphur, forming a compound of a dark violet colour, with a degree of metallic lustre, opaque, soft, and brittle. Sulphuretted hydrogen tarnishes silver rapidly, and from its continued action, thin scales of sulphuret are formed.

Silver unites with the greater number of the metals, suffering in general a diminution in its ductility and malleability, but acquiring greater hardness. It unites with gold without any loss of ductility, while it communicates to the gold hardness and elasticity; when the silver amounts to one-fifth of the mass, the colour is green, and this alloy is used for ornamental purposes. The alloy of gold and silver being more fusible too than gold, is em-



employed in soldering this metal. Copper added in small proportion to silver, renders it harder without much impairing its ductility, and hence this addition is usually made when it is to be fabricated into coin or plate. The standard silver of this country contains one part of copper to twelve.

Silver is used as the medium of exchange next in value to gold. To ornamental purposes it is well adapted by its lustre, and the purity and beauty of its colour. It is applied to the surface of other metals in various modes. The most substantial plating is a mechanical operation; a thin plate of silver being applied to a bar of copper, with a little borax between them, to facilitate their union when a sufficient heat is applied; the bar is afterwards passed through the rolling press; it is extended, and the silver, from its greater malleability, is likewise extended, so as to cover the surface of the copper. Other modes are, to apply an amalgam of silver to copper, driving off the quicksilver afterwards by heat, or rubbing on the surface mixtures of oxide or chloride of silver, with muriate of soda or ammonia, or supertartrate of potash, and applying heat so as to favour the reduction of the silver on the surface of the copper, and its adhesion on it. Silver is recovered from its intermixture with copper, by intermixed sulphuric and nitric acids, or by boiling it in sulphuric acid, the sulphate of copper which is formed being removed by washing, the sulphate of silver remaining insoluble.

The solution of nitrate of silver is used in analytic chemistry, to discover the presence of muriatic acid \* in any

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\* It is a common statement, that nitrate of silver is a test for chlorine; but if applied to uncombined chlorine, it is an incorrect expression, for free chlorine produces no precipitate in solution of nitrate of silver: it is when the chlorine is combined, as when in the state of muriatic acid, that this test discovers its presence. ED.



state of combination. Largely diluted, it forms what is named Indelible Ink, employed in marking linen which is to be bleached, lines traced with it becoming dark on exposure to light.

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### CHAP. III.—OF PLATINA.

THIS is a metal of modern discovery, the produce of the mines of Peru. It occurs always in the native state, generally in small grains of metallic lustre, a greyish-white colour, ductile and malleable, and having a specific gravity not less than 17. It is mixed with various earthy and metallic fossils, and is alloyed with a small quantity of iron, so as to be sensibly magnetic. But besides these foreign substances, it has within these few years been discovered, that there are associated intimately with the metal to which the name of Platina is still appropriated, not less than four distinct metals, formerly unknown. The history of these may be delivered after the history of platina itself. Platina has been found lately in Brazil, which appears to be less alloyed than that from Peru.

Platina in its native form is so infusible, that the grains can scarcely be agglutinated by the application of even the most intense heat: other methods therefore are necessary to obtain it in a metallic mass. The one which has been usually followed, is to dissolve crude platina in nitro-muriatic acid; on adding to this solution a solution of muriate of ammonia, a precipitate is thrown down, consisting of the oxide of platina in combination with portions of muriatic acid and ammonia: on urging this precipitate with a fire gradually raised to an intense degree,



the acid and ammonia are expelled, the oxide is reduced, and a spongy metallic mass is obtained, which, by pressure or percussion while at a red heat, is rendered more dense. The metal in this state is still, however, in general so imperfectly agglutinated, and it is at the same time so infusible, as not to be easily worked. It is therefore subjected to other methods. One of the most practicable in the large way, is to alloy it with arsenic, by which it is rendered so fusible as to be easily cast into bars; and the arsenic is afterwards volatilized by exposure to a fire gradually raised, until the platina is obtained malleable. Another is, to combine the spongy metallic platina with quicksilver; the solid amalgam is moulded when soft into bars: it quickly becomes hard, and is afterwards exposed to a heat sufficient to dissipate the quicksilver. It is then strongly ignited, until it is sufficiently ductile to admit of being forged. As obtained by any of these methods, it is still alloyed to a certain extent with the metals naturally associated with it, and processes considerably complicated are required to obtain pure platina.

Platina, in the dense state into which it is brought by the usual processes, is of a white colour, with a slight shade of grey, with metallic lustre: in hardness it is superior to the greater number of the metals; it is highly malleable and ductile: it can be drawn, by a method similar to that used with gold, into wire only  $\frac{1}{3000}$ th of an inch thick; and by great care, Dr Wollaston obtained specimens only  $\frac{1}{3000}$ th of an inch thick. Its specific gravity exceeds that of the other metals; and hence it is the heaviest known substance; the specific gravity has been estimated from 20.8 to 24, varying according as it has been more or less hammered, and as it is more or less alloyed. It suffers less expansion from heat than the other metals in general do, and it is also much inferior to them in conducting power.



Platina is a metal extremely infusible; it melts only in the focus of a powerful lens, or in the heat excited by oxygen gas directed on burning charcoal. The point at which it melts exceeds that at which the pyrometrical pieces of Wedgwood cease to contract, and cannot therefore be exactly estimated; it has been supposed to be higher than  $150^{\circ}$ , or even  $160^{\circ}$ , of the scale of this pyrometer. By the aid of fluxes, as of borax, its fusion may be effected with more facility. It so far partakes of the property of welding, otherwise peculiar to iron, as to soften at a heat much inferior to that necessary to melt it; whence two pieces of it by forging can be united.

Platina is not very susceptible of oxidation. Its lustre suffers no diminution from exposure to air or humidity; nor does it lose its metallic qualities when exposed to a high degree of heat, with the admission of atmospheric air. By a very intense heat, however, suddenly applied, as that from the discharge of an electrical battery, by which it is not only fused but volatilized, it is oxidated. It suffers also oxidation from the action of nitre at a high temperature. The composition of its oxide is best ascertained by precipitating it from its solution in nitro-muriatic acid. From the experiments of Berzelius and Dr Thomson, it is inferred that the equivalent of platina is 96, that the protoxide contains one atom of oxygen, 8, and the peroxide two of oxygen, 16; a third oxide is supposed also to exist, containing a proportion and a half of oxygen, or 12.

Platina is scarcely acted on by any of the acids, but the nitro-muriatic: even nitric acid boiled on it does not change its lustre. When heated in chlorine gas it is slowly acted on, forming a substance of a brown or olive colour. Nitro-muriatic acid is its proper solvent, and the muriate afforded by this solution is the only salt of this



metal that has been particularly examined. When the acid is composed of three parts of muriatic, and one of nitric acid, it dissolves the largest proportion of the metal: as the mutual action proceeds, a black powder is deposited, which consists principally of some of the foreign metals contained in native platina. The solution is of a dark reddish-brown colour, and by evaporation it affords crystals of the same colour, usually of various shades.

This solution is decomposed by the alkalis; when potash is added, in a short time small reddish octohedral crystals are deposited; if an additional quantity of alkali be added, a yellow flocculent precipitate is thrown down. Ammonia gives rise to similar results. Soda throws down only the yellow precipitate. The yellow precipitate is a triple muriate of platina and potash or soda; or, as it is supposed by others, notwithstanding the water it contains, a compound of bi-chloride of platina, and chloride of potassium or sodium: the red precipitate contains a portion of one of the metals associated with native platina, iridium, as is immediately to be stated.

From the nature of these precipitates, they are likewise formed by adding to the solution of muriate of platina a solution of a neutral salt containing these alkalis. Thus, precipitates are formed by muriate of potash, or muriate of ammonia, and even by the sulphates or nitrates of these alkalis: this is a property characteristic of platina. The precipitate, from the addition of muriate of ammonia, is decomposed by a red heat, and pure metallic platina is left in the form of a spongy mass, composed of minute particles. It is in this state that it acts upon mixtures of oxygen with hydrogen and other gases, in the manner which has been stated.

The solution of muriate of platina is decomposed by several of the metals and metallic salts, which de-oxidate it



partially or entirely. Muriate of tin is, by an action of this kind, a very delicate test of it, a bright red colour being assumed when a few drops are added to the solution of platina diluted with a large quantity of water. Hydriodic acid, according to Professor Silliman, is even a better test, producing, when dropt into a solution of platina, a deep reddish colour. It is not precipitated, as the greater number of metallic salts are, by prussic acid or the prussiates. It is decomposed by heat, chlorine being evolved, and oxide of platina left.

Platina and sulphur do not unite by fusion, owing probably to their weak affinity, and the extreme infusibility of the metal. Mr E. Davy has effected this combination, by heating the ammoniaco-muriate of platina with sulphur, and also by exposing to heat a mixture of platina and sulphur in an exhausted tube hermetically sealed. Platina combines too with the alkaline sulphurets; and sulphuretted hydrogen added to its solution causes precipitation, from the formation of a ternary compound of platina, sulphur, and hydrogen.

The sulphuret of platinum acted on by nitric acid becomes a sulphate of platina. Its solution in water is said to be an excellent test for detecting gelatin. A fulminating preparation of platina may be obtained by adding ammonia to solution of sulphate of platina, and boiling the precipitate in solution of potash to dryness. It is a brown powder, which explodes violently when heated; it is a compound of ammonia and oxide of platina, containing also a portion of water.

Platina combines with phosphorus, when they are heated together; the compound is of a white colour; it is fusible, and by a strong heat is decomposed, the phosphorus being expelled; hence the combination with phosphorus has been employed as a method of rendering platina fusible and capable of being worked.



Platina combines with the greater number of the metals. With gold an alloy is formed of a yellowish-white colour, highly ductile and elastic, and of a specific gravity of 19. The alloy with silver is of a dull colour, and harder than pure silver. With quicksilver platina can be combined when it is in that spongy state in which it is procured by the decomposition of the ammoniaco-muriate by heat. Mr Daniell has lately taken advantage of the affinity between platina and mercury to prevent the deterioration of barometers, which he has shown always happens after some time from the entrance of air between the glass and the mercury. A ring of platina fixed at the lower end of the tube becomes *wet* as it were with the mercury, and their adhesion prevents the entrance of air.

Platina is a metal of considerable value from its hardness, its infusibility, and from being acted on by very few chemical agents. It is from these qualities adapted to many chemical purposes, and is employed in the construction of tubes, evaporating basons, and crucibles, and in the form of wire for galvanic experiments. From its property of suffering less expansion than other metals from heat, and not being liable to rust, it is superior for the construction of the pendulum-spring of watches. Other metals, copper for example, can be covered with a coating of it, by applying an amalgam prepared from the trituration of the spongy platina with five parts of quicksilver, to the surface, and applying heat so as to favour the volatilization of the quicksilver, and the adhesion of the platina. Brass or steel may be coated with platina by a process similar to that by which they are gilded,—adding sulphuric ether to a solution of platina, removing the ethereal solution from the acid liquid beneath it, and dipping into this the polished steel or brass. Platina has also been applied to porcelain-painting, by means of the



flux by which gilding or painting is effected, and serves to diversify the painting with gold.

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CHAP. IV.—OF IRIDIUM.

THIS is the first of the metals which, as has been stated, have been found to exist in native platina; it was discovered by Mr Smithson Tennant. It constitutes the principal part of the black powder deposited during the solution of the crude platina in nitro-muriatic acid, and which, being also in part dissolved, communicates to the solution and the crystals it affords by evaporation, a red colour. It may therefore be obtained, either from the black powder, or from the dark red precipitate which is thrown down from the solution by muriate of ammonia, which consists chiefly of the oxide of iridium, with portions of ammonia and muriatic acid.

It is obtained from this precipitate by the action of heat alone, the acid and ammonia being expelled, and the oxide reduced; the black powder affords it when heated merely before the blow-pipe: it loses its black colour, becomes white, and acquires metallic lustre. In this state, however, the metal is not perfectly pure; it has an alloy of iron, and of another metallic substance, discovered by Mr Tennant to be a new metal, which he named Osmium. To obtain the iridium free from these, more complicated processes are necessary, consisting primarily in subjecting the black powder to the alternate action of potash in fusion, and muriatic acid: the alkali dissolving the other metals, the acid dissolving the iridium with a portion of iron. From the muriatic solution, the iridium may be



obtained, by precipitating it in its metallic form by immersing plates of zinc in the solution ; or by evaporating the solution to dryness, removing the muriate of iron by alcohol, and afterwards reducing the muriate of iridium by exposure to heat.

This metal is of a greyish-white colour, brittle and hard ; the rigidity and hardness of common platina, according to Fourcroy and Vauquelin, depend upon it. The specific gravity of a porous globule of it, fused by the heat of a galvanic battery, was found to be 18.68. It is oxidated by heat, and its oxide is volatile ; by applying a strong heat to crude metallic platina in an earthen retort, a sublimate of a blue colour is obtained, which is oxide of iridium ; or by calcining the metal with potash, its oxide is formed by the action of the air, and combines with the alkali. In its saline combinations, it appears to exist in different states of oxidation. Thus the solution of it in muriatic acid is of a deep green colour : by dilution with water, it becomes blue ; when heated it becomes red ; and when in this state it is submitted to the action of substances capable of de-oxidating it, the red colour is removed, and the green or blue restored : the oxide, therefore, giving the red colour, seems to contain the larger proportion of oxygen. It is from these changes of colour in its solution, which are characteristic of this metal, that Mr Tennant named it Iridium. Dr Thomson infers its equivalent to be 30.

Iridium, in its metallic state, is scarcely acted on by any acid : it is more soluble when alloyed with platina. When oxidated, it dissolves easily in the acids ; the solution in nitric acid is of a red colour ; in sulphuric or muriatic acid it is green or blue, according to the state of dilution ; the alkalis throw down from these solutions precipitates of the same colour, which are generally triple salts.



The fixed alkalis act more powerfully on iridium than the acids do. When it is heated with potash in contact with the air it is oxidated, and combines with the potash; on adding water a solution is obtained of a rich blue colour, consisting of the oxide dissolved by an excess of alkali. The earths, particularly alumina, shew a strong attraction to the blue oxide of iridium.

It combines with some of the metals; both gold and silver alloyed with it remain malleable; the iridium is not separated by cupellation, but only by solution in nitro-muriatic acid.

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CHAP. V.—OF OSMIUM.

WHEN the black powder which is precipitated during the solution of native platina in nitro-muriatic acid is heated with potash or soda, one portion of it becomes soluble in muriatic acid, another portion of it enters into union with the alkali, forming a compound soluble in water. The latter is the oxide of a new metal, to which, from the strong smell it has in its oxidated state, Mr Tennant gave the name of Osmium.

The oxide of osmium, obtained in combination with the alkali, is separated by the addition of an acid; and what is a singular property, it can be obtained dissolved in water by distillation. The solution is limpid, has a sweetish taste, and a pungent peculiar smell. It does not redden the vegetable colours, but paper stained with the colour of violet, exposed to the vapour from it, becomes grey. This oxide is obtained more concentrated, by distilling the black powder from crude platina with nitre: a fluid distils over, which on cooling forms a colourless semi-



transparent solid mass, soluble in water. This concentrated solution stains the skin of a dark colour.

Oxide of osmium is obtained by precipitating it from its solution in acids by zinc, and then exposing it to heat; it is volatilized, and condenses in crystals: is white, transparent, and brilliant; as fusible as wax; has a strong caustic taste, and an insupportable smell. It parts with its oxygen easily; Dr Thomson was unable, however, to ascertain its composition. The greater number of the metals deprive its solution of smell, and a grey powder is precipitated, consisting of osmium, with the oxide of the metal by which it has been precipitated. If quicksilver be employed to precipitate it, an amalgam is obtained; by applying heat, the quicksilver is volatilized, and a powder remains of a dark grey or blue colour, which is metallic osmium. This is the process by which Mr Tennant procured it, and it is the only state in which it has been procured. Exposed to a strong white heat, in a cavity in a piece of charcoal, Mr Tennant found that it was not melted, nor did it suffer any apparent alteration. When heated with gold, or with copper, it melted, and formed alloys with these metals. Heated with the access of air, it is oxidated, and the oxide evaporates, diffusing its peculiar smell.

Osmium dissolves in muriatic acid, and still more readily if a little nitric acid is added; it combines with chlorine, assuming a deep green colour, and then forming a liquid of a reddish-brown colour. Oxide of osmium unites with the fixed alkalis, and forms compounds soluble in water, of a yellow colour. A striking property by which this metal may be recognised, is that of its solution assuming a purple colour, which soon becomes of a vivid blue, on the addition of infusion of galls. The solution of oxide of osmium becomes yellowish, on the addition of



ammonia, or of carbonate of soda ; and a bright yellow is acquired from the action of lime. The peculiar smell, and the volatility of this oxide, are still more characteristic, and distinguish it from every other substance.

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CHAP. VI.—OF RHODIUM.

DR WOLLASTON, submitting to examination the liquid which remains after the precipitation of the solution of crude platina in nitro-muriatic acid by muriate of ammonia, discovered in it two metals, one which he named Rhodium, the other Palladium. The following is the process by which the first of these metals is obtained.

Crude Platina, having been dissolved in nitro-muriatic acid, was precipitated by muriate of ammonia. In the remaining liquid, a piece of zinc was immersed, until no farther action appeared to be exerted on it. The iron of the crude platina remained in solution : the other metals were precipitated in a black powder. This precipitate, which by previous experiments was known to contain platina, rhodium, palladium, copper, and lead, was digested in dilute nitric acid, by which the two latter metals were removed ; and by digestion in nitro-muriatic acid, the greater part of the remainder was dissolved. To the solution, a portion of common salt was added ; and the whole being evaporated to dryness, the solid matter was washed repeatedly with alcohol. There remained undissolved, the triple salt of rhodium, which was thus freed from the other salts. When dissolved in water, and decomposed by zinc, a black powder was obtained, in quantity corresponding to about 4 grains from 1000 grains of crude platina dissolved. This powder, exposed to heat, with borax, ac-



quired a white metallic lustre, but appeared infusible by any degree of heat: it has lately been fused by Messrs Stodart and Faraday. Like platina, it is rendered fusible by arsenic, as it also is by sulphur: the arsenic or the sulphur is expelled by a continuance of the heat: but the metallic button obtained does not become malleable. Its specific gravity is 11. Dr Thomson infers its atomic weight to be 44, and that two oxides of it exist, the protoxide with one atom of oxygen, 8, and the peroxide with two atoms of oxygen, 16. The former is of a black colour, the other yellow.

Rhodium is insoluble in all the acids, simple or compound; but if it be alloyed with copper, lead, or bismuth, it becomes soluble in nitro-muriatic acid, probably from the effect of the mutual affinity of the salts of the two metals. The oxides are soluble in the acids from the triple muriate of soda and rhodium; the pure alkalis throw down the yellow peroxide, which is redissolved by adding an excess of alkali. The solution in muriatic acid is of a rose colour, whence the name of the metal is derived; it does not crystallize by evaporation; muriate of ammonia or of soda causes no precipitation from it; the solution in nitric acid also does not crystallize; the rhodium is precipitated from it by silver, copper, and other metals.

Rhodium unites with all the metals, quicksilver excepted. Its alloys with gold and silver are malleable; the colour of gold is little altered, even when the rhodium amounts to one-sixth of the mass.

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#### CHAP. VII.—OF PALLADIUM.

THIS metal exists with rhodium in the solution of native platina, after the addition of muriate of soda, in the state



of a soda-muriate; alcohol dissolves this with the soda-muriate of platina; the latter may be precipitated by muriate of ammonia, and the palladium procured by means of prussiate of potash. Or a simpler process, given by Dr Wollaston, is to add to a solution of crude platina a solution of prussiate of mercury; a flocculent precipitate of a yellowish colour gradually accumulates; this is prussiate of palladium, and, when decomposed by heat, affords the metal in a pure state.

Palladium is of a greyish-white colour, and when polished has considerable lustre; it is ductile and very malleable; in hardness it is superior to forged iron; its fracture is fibrous; its specific gravity is from 11 to 11.8; like platina, it is less expansible, and is a less perfect conductor of heat, than the greater number of the metals. It requires a heat of considerable intensity to fuse it: it is volatile at an intense heat, and seems to be combustible. Heated under exposure to the air, it is not oxidated, and its oxide obtained by other methods is reduced by heat: in this oxide 14 of oxygen are combined, according to Berzelius, with 100 of the metal: the atomic weight of palladium appears to be 56, and this is combined in the oxide with one atom of oxygen, 8.

This metal is acted on by a number of the acids. Nitric, sulphuric, muriatic, and nitro-muriatic acids acquire from it a rich red colour, and dissolve a portion of it. These solutions are decomposed by the alkalis and earths, precipitates of an orange colour being thrown down, which are partly redissolved if the alkali is in excess. The sulphate, nitrate, and muriate of potash, or of ammonia, produce precipitates of an orange colour, which are triple salts.

The alkalis act on palladium, even in its metallic state. Exposed to the action of melted potash, it loses its lustre and part of its weight, and part of the metal is oxidated



and combined with the alkali. Ammonia digested on it acquires a bluish tinge, and holds a small portion of oxide in solution, the oxidation in these cases being formed by the action of the air.

All the metals, with the exception of gold, silver, and platina, precipitate palladium in its metallic state from its saline solutions. Green sulphate of iron also throws it down. Muriate of tin forms a precipitate of a dark orange or brown colour; sulphuretted hydrogen gives a precipitate of a dark-brown colour; prussiate of potash one of an olive colour; prussiate of mercury, a precipitate of a yellowish-white colour; and as this re-agent does not precipitate platina, this affords a very good test to distinguish between these metals. This precipitate by prussiate of mercury from the nitrous solution of palladium, explodes when heated to  $500^{\circ}$  of Fahrenheit.

Palladium combines with sulphur, and is instantly fused when sulphur is thrown upon it at a high heat. The sulphuret is white and brittle: it contains 0.22 of sulphur.

It forms combinations with a number of the metals. Its alloy with gold is of a grey colour, harder than gold, but less ductile even than palladium. Its alloy with silver is grey and hard. Platina and palladium enter into fusion at a heat not higher than that at which palladium melts, and an alloy is formed similar to the preceding in colour and hardness. Its other alloys are hard and brittle.

Palladium has been discovered by Mr Cloud as a constituent part of a native alloy with gold, free from platina; and Dr Wollaston has observed it in a distinct form in the grains of native platina from Brazil.



## CHAP. VIII.—OF QUICKSILVER, OR MERCURY.

THIS is distinguished from all the metals by its fluidity at common natural temperatures; it becomes solid at  $-39^{\circ}$  of Fahrenheit, and has then considerable malleability. In its liquid state it is perfectly opaque, and has the metallic lustre; its specific gravity is 13.5. In becoming solid it suffers considerable condensation, equal, as has been calculated, to  $\frac{1}{23}$  of its volume: whence its specific gravity is increased in the solid state to 14.46, or 15. In its congelation it assumes a crystalline structure, and it can even be obtained in small octohedral crystals.

Quicksilver occurs native in small quantity. In its usual state it is mineralized by sulphur; and from this ore it is extracted by distillation with lime or iron. It is purified by distilling it a second time from a portion of iron-filings.

The temperature at which quicksilver boils under a mean atmospheric pressure, is between  $600^{\circ}$  and  $700^{\circ}$  of Fahrenheit, being stated on different authorities at  $655^{\circ}$ ,  $662^{\circ}$ , and  $672^{\circ}$ .

At the same temperature as that at which it is volatilized, it is oxidated by the action of the air. When kept boiling gently, its lustre diminishes, a film forms on its surface, and scales of a brick-red colour accumulate, the oxygen of the air being absorbed. The operation is not easily conducted without loss from the volatilization of the mercury; but it is best performed in a glass matrass, with a shallow bottom, and the neck drawn out to a small aperture, a small quantity only of quicksilver being put into it, and the heat being applied steadily by a sand-bath. This red oxide contains 7.31 of oxygen in 100



parts, or it consists of one atom of mercury, 200, and two of oxygen, 16, = 216; it is reduced by the heat of ignition to the metallic state.

Besides this peroxide, a protoxide of mercury may be obtained, by agitating quicksilver for some time; it is a grey powder, which is mixed, however, with a portion of metallic mercury. This oxidation appears to be effected with more facility, when the continuity of the quicksilver is interrupted, and its surface is extended by the interposition of any viscous matter, as mucilage, honey, or fat; and in this way are formed a number of medicinal preparations, the efficacy of which depends on this oxide: it may be procured also by boiling calomel in liquid potash. It contains 3.78 *per cent.* of oxygen, or is composed of an atom of mercury, 200, and one of oxygen, 8, = 208.

The greater number of the acids act on quicksilver, or at least are capable of combining with its oxides.

Sulphuric acid exerts little action upon it in the cold, but if heat be applied it is decomposed, the quicksilver is oxidated, sulphurous acid is disengaged, and the oxide combines with the remaining acid: This proto-sulphate of mercury crystallizes in slender prisms, forming a mass, soft, and partly liquid, composed of these crystals. This saline mass is very acrid, deliquescent, and soluble in water. If it is urged with a heat gradually raised until the mass becomes dry, the metal is more highly oxidated, and a portion of the acid is dissipated. On pouring on this dry mass boiling water, it acquires a lively yellow colour, forming an insoluble powder known by the appellation of Turbith Mineral, or Yellow Sub-sulphate of Mercury. The water in this process produces the usual effect which it has when it decomposes metallic salts. Exerting a stronger attraction to the acid than to the metallic oxide,



it combines principally with the former ; but, from the influence of quantity on chemical affinity, the acid carries with it a portion of the oxide, and conversely, from the operation of the same force, the oxide which is precipitated retains a portion of the acid combined with it ; the neutral sulphate is thus resolved into a super-sulphate which the water dissolves, and a sub-sulphate which remains undissolved. This sub-sulphate is chiefly used in preparing corrosive sublimate and calomel.

Nitric acid acts on quicksilver with facility, oxidating it, and combining with the oxide, forming a perfect solution. The product of this action varies considerably, particularly with regard to the state of oxidation, according to the circumstances under which it is exerted. If the acid is diluted with rather more than an equal part of water, and if the action is not accelerated by heat, the protoxide only is formed, and the salt is the proto-nitrate of mercury. If the acid is less diluted, and if its action on the metal be promoted by heat, the peroxide is produced, and the compound is the per-nitrate of mercury. Both these solutions, when concentrated, crystallize, a mass being deposited, consisting of a congeries of slender prisms. Both salts are corrosive, deliquescent, and soluble in water. If the solution of the per-nitrate is poured into water, a partial decomposition happens, similar to that of sulphate of mercury, and a yellow insoluble sub-pernitrate of mercury is precipitated. Nitrate of mercury is decomposed by the alkalis and earths, and in these decompositions are well displayed the differences which arise from the different states of oxidation of the metal. By potash, soda, or lime, added to the solution of the proto nitrate, a precipitate of a greyish colour, with a tinge of yellow, is thrown down ; from the solution of the pernitrate, the precipitate is yellow, more or less bright. These precipi-



tates are sub-nitrates, the oxide separated by the alkali retaining a portion of the acid combined with it.

The action of ammonia on these solutions is more peculiar. From the solution containing the mercury at a high state of oxidation, it throws down a white precipitate, which is a ternary combination of the oxide with portions of the acid and alkali. From the solution at which the metal exists at the minimum of oxidation, it throws down a precipitate of a dark grey or blue colour. The grey precipitate by ammonia (*Oxidum Hydrargyri Cinereum* of the Pharmacopœias) is a preparation much used in medicine. It is a mild mercurial, and is very similar in its operation on the system to the mercurial preparations formed by trituration. To obtain it of uniform composition, it is necessary to use every precaution to moderate the action of the nitric acid on the metal, as by free dilution with water, and by avoiding the application of heat.

If the solution of mercury in nitric acid be evaporated to dryness, a mass is obtained of a yellowish colour, which, when urged with a heat gradually raised, becomes of a bright red, much of the acid being expelled or decomposed. This is a preparation which has been known under the name of Red Precipitate of Mercury. When properly prepared, it is in scales of a brilliant red colour. It is not a pure oxide, but a sub-nitrate, and is accordingly different in its appearance and qualities from the red oxide obtained by the action of atmospheric air at a high temperature. That a portion of acid does remain in it, may be rendered apparent by the simple experiment of boiling it in water, the liquor, when filtered, having a metallic taste, and giving, as I have found, a precipitate with water of ammonia or carbonate of potash. It is employed as an escharotic, and this quality probably depends principally on the portion of acid it contains.



Muriatic acid does not act on quicksilver, and according to the new view of its nature, it is supposed to be incapable of combining with the protoxide, and to exist in union with the peroxide only when in solution. The compounds which were before considered as muriates, are now regarded as metallic chlorides. There are two of them, the bichloride of mercury, and the chloride of mercury. These two preparations are of importance from their medicinal use; they have been long known, the former by the name of Corrosive Sublimate of Mercury, the other by the name of Sweet Sublimate of Mercury, or Calomel. They may be formed directly by exposing mercury to chlorine gas, with or without heat, but are usually obtained by easier methods.

The process given in the Pharmacopœias to obtain the first of them, consists in dissolving quicksilver in sulphuric acid with the aid of heat. By continuing the application of heat, the per-sulphate of mercury is formed, and is obtained dry; it is then mixed with twice its weight of chloride of sodium (dry muriate of soda,) and the mixture being put into a glass matrass to which a capital is adapted, heat is applied by the medium of a sand-bath, and continued while any matter is sublimed. A double decomposition is produced; the sulphuric acid and oxygen of the sulphate of mercury pass to the sodium of the chloride of sodium, forming sulphate of soda, and the mercury unites with the chlorine present, which being in double proportion, bichloride of mercury is produced. Another process consists in exposing a mixture of subnitrate of mercury, chloride of sodium, and dry sulphate of iron, to heat. In either case the bichloride of mercury, being volatile, is sublimed, and it condenses in the form of a crystalline cake in the upper part of the matrass. If sublimed more slowly, it is obtained in the form



of needle-like crystals. It also crystallizes from its watery solution in prisms.

This substance is soluble in water, requiring about 20 parts at  $60^{\circ}$  for its solution, and not more than 2 parts at  $212^{\circ}$ ; it may be conceived to be converted in the solution into a muriate of mercury. It is also soluble in alcohol. Its taste is styptic; it is extremely corrosive, and acts as a violent poison. It is decomposed by the alkalis and earths, which precipitate from its solution the orange or red coloured peroxide. Ammonia forms a white precipitate, which is a ternary compound, consisting of one atom of the peroxide 216, and one of muriate of ammonia, 54, = 270. This has been in use as a mild escharotic, under the name of White Precipitate of Mercury. Muriate of ammonia, mixed with the muriate of mercury, renders it much more soluble in water, and forms with it a compound which can be obtained crystallized: muriates of soda, potash, barytes and magnesia, act in a similar manner. Sulphuretted hydrogen throws down from the solution of corrosive sublimate precipitates of a dark brown colour, which appear to consist chiefly of the sulphuretted oxide. A number of the metals decompose it by abstracting the oxygen of the oxide, either partially or entirely; and it even suffers a partial decomposition of this kind from vegetable extractive matter. It consists of two atoms of chlorine, 72, and one of mercury, 200, = 272.

As corrosive sublimate is, next to arsenic, the most virulent of the metallic poisons, and hence, when administered from accident or design, speedily occasions death, it is useful to be acquainted with tests which may detect its presence. The following will be sufficient, as there is less risk of mistake respecting it than there is with regard to arsenic. After sudden death suspected to arise from



poison, the stomach should be secured and its contents examined. If a portion of a powder is obtained, it is more likely to be oxide of arsenic than corrosive sublimate, as the latter is more soluble: it may be heated in a coated glass tube, when it will be sublimed to the upper part of the tube in the form of a white shining crust. If this crust be dissolved in water, and lime water be added, an orange-coloured precipitate will be produced. Or, if a drop of dilute solution of carbonate of potash be added, it will cause at first a white precipitate, but a farther addition of the test will produce an orange precipitate. Solution of sulphuretted hydrogen will throw down from a liquor containing corrosive sublimate a precipitate of a dark colour, which, when dried, may be volatilized by a strong heat without emitting any odour of garlic. Ammonia throws down a white precipitate, which is a triple salt of muriatic acid, ammonia and oxide of mercury: when heated, this becomes yellow, and then red. A single drop of nitrate of tin will occasion a dark brown precipitate. This, according to Dr Bostock, is an exceedingly delicate test. Any of these precipitates rubbed on a bright copper plate will render it white. Mr Sylvester has shown that corrosive sublimate may easily be detected by means of galvanism. A piece of zinc or iron wire is to be twice bent at right angles, and its two extremities fastened to a small gold ring; a few drops of diluted sulphuric acid are then poured on a horizontal glass plate, and at a little distance a little of the suspected liquor: the fluids must touch each other at their edges. The wire and ring are then so placed, that the former touches the acid, and the latter the liquor, when, if even a very minute portion of mercury exists in it, the part of the ring touched by the liquor will be covered with reduced mercury. A simpler method, depending on the same principle, is merely to drop a



small quantity of the suspected liquor on a piece of gold, and to bring in contact with it a key or some piece of iron, so as to form a galvanic circuit, when the gold will be immediately whitened. A solution of nitrate of silver may produce a similar white appearance; but this is merely a precipitate upon the gold, and hence is easily wiped off, while the other is a real combination or amalgamation. Various metals, as iron, zinc, and copper, it has also been stated, precipitate mercury from solution of corrosive sublimate.

Where a poisonous dose of corrosive sublimate has been swallowed, the best antidote is the white of eggs; the albumen converts it into calomel, and, remaining combined with it, renders it almost inert: with the aid of mucilaginous draughts and vomiting, its fatal effects may be prevented. Wheat flour diffused in water has also been recommended as an antidote.

The process by which the other chloride of mercury is formed, is an indirect one. It consists in triturating the corrosive sublimate with nearly an equal weight of metallic mercury, facilitating the trituration by the addition of a little water, and continuing it until the globules are no longer apparent. The powder dried is put into a glass matrass, and sublimed by heat, applied by the medium of a sand-bath; an additional equivalent of mercury thus enters into combination with the two atoms of chlorine, or a proto-chloride is formed. As this new combination is not perfect on the first sublimation, the mass is reduced to powder, and sublimed a second, or even a third time. The sublimate is then obtained perfect, and free from metallic mercury: it is reduced to a fine powder by levigation, and is thoroughly washed and dried. Calomel, as it is commonly called, prepared in this manner, consists of one atom of chlorine, 36, and one of mercury, 200, = 236.



In the last London Pharmacopœia a different process is given for obtaining it, in which the previous preparation of corrosive sublimate is not required: Two pounds of mercury are boiled with 30 ounces of sulphuric acid to dryness; this dry persulphate of mercury is rubbed with other two pounds of mercury until the globules disappear; the salt is thus converted into a proto-sulphate; a pound and a half of common salt are added, and heat applied, when calomel will be sublimed. This is reduced to an impalpable powder, and is then, to remove any corrosive sublimate which may be formed in the process, washed repeatedly with cold distilled water in which a quantity of muriate of ammonia or muriate of soda is dissolved, which, it has been stated, renders corrosive sublimate more soluble. This process is said to have considerable advantages over the older method.

Calomel, obtained by sublimation, is in the form of a dense mass of crystalline structure, composed of short prisms; and when sublimed slowly, it is obtained in tetraedral prisms, or in octohedrons. In its dense state, it has a specific gravity of 7.1; it is semi-transparent, with a slight tinge of yellow. It is volatile, as is obvious from its mode of formation; it is so sparingly soluble in water, as to require above 2000 parts for its solution. It is insipid, has no escharotic power, and is mild in its operation on the system. It is decomposed when boiled with muriate of ammonia or soda, which converts it into mercury and corrosive sublimate.

Chlorate of mercury is formed by transmitting chlorine gas through water in which red oxide of mercury is diffused. Along with crystals of the corrosive muriate, this salt is obtained in crystals, which are more soluble than it in water.

Mercury combines also with iodine, and in two propor-



tions; the iodine is of a yellow colour, the bin-iodide or per-iodide of a red colour; they are both insoluble, and hence no hydriodates of mercury exist.

Mercury is scarcely acted on by the other acids; but its oxides combine with the greater number of them. These combinations may be effected by digesting the oxide in the acid; but a preferable mode is to add to the nitrous solution of mercury, either the acid designed to be combined with the oxide of mercury, or a solution of a neutral salt which contains this acid. Thus, if phosphoric acid be added to the nitrous solution of mercury, a phosphate of mercury is formed: or if a solution of phosphate of soda be added, the same compound is obtained, the soda attracting the nitric acid, and the phosphoric acid combining with the oxide of mercury. In the same manner may be effected the combinations of the oxides of this metal with any other acid. None of these compounds are important, or applied to any use.

The oxides of mercury precipitated by the alkalis, especially by ammonia or lime, if dried with exposure to light, and triturated with 1-6th of their weight of sulphur, detonate on being heated. A more powerful fulminating mercurial preparation was discovered by Mr Howard. It is obtained by dissolving 100 grains of mercury in an ounce and a half of nitric acid, with the assistance of heat; the solution, when cold, is poured upon two ounces of alcohol by measure; a moderate heat is applied, till an effervescence is excited, and a precipitate is formed: this washed and dried, forms the fulminating mercury:  $1\frac{1}{2}$  or 2 grains of it, struck upon an anvil, explode violently; and the same effect is produced by a strong electrical discharge, by sudden friction, or exposure to heat. Mr Howard supposed this preparation to consist of oxide of mercury, oxalic acid, and nitrous etherised gas; and its



detonation has been attributed to the sudden combination of the oxygen with the carbon and hydrogen of these substances, forming aqueous vapour, and carbonic acid, and disengaging nitrogen gas, while, at the same time, so much caloric is rendered sensible, that not only is the elasticity of these gases much increased, but the metal is converted into highly elastic vapour. But, according to Liebeg and Gay-Lussac, the explosive property is owing to the peculiar acid, the *fulminic* already noticed, which exists in this preparation, in union with oxide of mercury. It may be transferred, they affirm, to other bases, but cannot exist in an insulated state; it has been stated to consist of cyanogen and oxygen with a metallic element, which in this case will be mercury.

Quicksilver combines with sulphur in two proportions. The proto-sulphuret, or black sulphuret of mercury, is obtained by triturating sulphur with quicksilver; the globules disappear, and a black powder is formed, which used to be called *Ethiops* mineral; it consists of one atom of mercury, 200, and one of sulphur, 16, = 216. The bi-sulphuret is formed by heating sulphur with mercury, when a substance sublimes of a vivid red colour; this is the cinnabar or vermillion of commerce, which may also be obtained by acting on mercury, with hydro-sulphuret of ammonia: it is composed of one atom of mercury, 200, and two of sulphur, 32, = 232.

Quicksilver combines with most of the metals, except iron, cobalt, antimony, and nickel. These compounds are brittle and soft; and when the mercury is in large proportion, are fluid. They are named Amalgams. The amalgam of it with tin is used in silvering glasses: that with gold or silver, in gilding or silvering the other metals: and from its property of amalgamating so easily with these two metals, quicksilver is employed in extract-



ing them from the foreign substances with which they are naturally mixed.

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CHAP. IX.—OF COPPER.

COPPER is of a red colour, with a shade of yellow, having considerable lustre, but liable to tarnish and rust from exposure to the air. It is moderately hard, and has considerable ductility and malleability. Its specific gravity is 8.8, according to Dr Thomson 8.43. It has a sensible odour, especially when heated or rubbed, a styptic unpleasant taste, and is peculiarly noxious to animal life.

Copper occurs in nature in the metallic state, and also mineralized by oxygen, by sulphur, united with other metals, and in the state of oxide combined with different acids. It is chiefly extracted from those ores in which it is associated with sulphur, these being most abundant. The ore is roasted by a low heat, the metal is reduced, melted, and by repeated fusions is obtained pure.

Copper melts at a full white heat, and by slow cooling may be crystallized. It suffers oxidation at a lower temperature from the action of the air, thin scales of oxide forming on its surface when it is heated to redness. At a higher heat it burns with a green flame. Exposure to air and humidity at natural temperatures converts it into a green rust, which is the oxide combined with a portion of carbonic acid. There appear to be two oxides of copper: the protoxide is of a red colour: it exists in some of the salts of copper, and also forms the red copper ore; it consists of one atom of copper, 64, and one of oxygen, 8, = 72. The peroxide is of a brown or black colour: it



is formed by exposing the metal to the action of the air at a high temperature, or by igniting the pernitrate, and is composed of one atom of copper, 64, and two of oxygen, 16, = 80. It may be remarked, however, that some chemists of high reputation, as Dr Wollaston, Prout and Thomson, are of opinion, that the true atomic weight of copper is 32, instead of 64; in which case the peroxide here mentioned will be the proper protoxide, and what has been termed the protoxide will be a suboxide. The blue and green precipitates thrown down from the salts of copper by the alkalis and earths are not pure oxides, but hydrates, containing from 10 to 20 parts of combined water in 100.

Copper is oxidated and dissolved by the greater number of the acids, and forms with them in general soluble and crystallizable salts, of a green or blue colour.

Sulphuric acid, either concentrated or diluted, oxidates it, and combines with the peroxide, especially when its action is promoted by heat. The solution is of a blue colour, and by evaporation affords crystals of the same colour, in the form of rhomboidal prisms: they are soluble in four parts of water at 60, and in two parts at 212°; by heat, the acid is partially expelled. This salt is the blue vitriol of commerce; and is usually obtained either by evaporation of the solution of it formed by the infiltration of water through copper mines, or by exposure of sulphuret of copper to the action of air and humidity, until the sulphur is converted into sulphuric acid, and the metal is oxidated and combined with it: it is a bi-persulphate of copper, or consists of two equivalents of sulphuric acid 80, and one of peroxide of copper 80, with 10 atoms of water, 90, = 250. A sub-sulphate of copper is formed by abstracting part of the acid of the sulphate by an alkali.



Nitric acid acts on copper with much facility, the metal attracting a portion of its oxygen, nitric oxide gas being disengaged, and the oxide combining with the remaining acid. The solution is of a green or blue colour. When evaporated, it affords prismatic crystals of a deep green colour, deliquescent, and easily soluble in water. This salt, from the facility with which it parts with oxygen, acts with energy on a number of substances. Thus it detonates when struck with phosphorus, and it burns several of the metals. If wrapt in tinfoil, the tin is oxidated, and frequently with such rapidity as to produce appearances of inflammation. To succeed in this experiment, the salt must not be in a perfectly dry state, but a little water must be added to it; this has been supposed to operate by communicating that fluidity necessary to chemical action, and the experiment has often been produced as affording a proof of this. I have found, however, that it depends on a different cause—the concentration of the acid; for if the solution be strongly evaporated, and the salt employed while it is still a little warm, though it be perfectly soft, and even humid, it does not act on the tin, until a little water is added. It is therefore an example of the singular fact, established by more direct experiments, that nitric acid highly concentrated does not act on metals, but requires the presence of a portion of water.

Muriatic acid dissolves copper slowly when the atmospheric air is admitted: if it is excluded, the action is very inconsiderable unless heat is applied; the solution is of a green colour, and by evaporation slender prismatic crystals are obtained, deliquescent, and very soluble in water. The salt is decomposed by heat, chlorine being disengaged; it is a bi-permuriate of copper, consisting of one atom of peroxide of copper, 80, two of acid, 74, and four of water, 36, = 190. A proto-muriate is obtained by in-



including copper-filings in a phial closely stopt, with a solution of green muriate of copper, the solution gradually becomes colourless, the metallic copper attracting a portion of the oxygen of the dissolved copper; but that the solution still holds the metal dissolved at a lower degree of oxidation, is proved by the fact, that if the air be admitted, a blue tint is soon produced, and appears first at the surface of the liquid. By the addition too of muriate of tin, a substance which powerfully abstracts oxygen, to a solution of muriate of copper, a white muriate is precipitated, and this, by an addition of acid, forms a colourless solution. A green muriate of copper may also be obtained by exposing plates of copper to the vapour of the acid; the green copper sand of Chili appears to be a submuriate of copper; it is a submuriate also which is formed on the surface of the copper sheathing of vessels from the action of the sea water. When the muriates of copper are thoroughly dried, they are converted into chlorides of copper; these may be formed also by burning copper in chlorine gas. The proto-chloride, which may likewise be obtained by heating two parts of corrosive sublimate with one of copper-filings is easily fusible, insoluble in water, but soluble in muriatic acid: it consists of one atom of copper, 64, and one of chlorine, 36. The perchloride is of a yellowish or greenish colour; it contains two atoms of chlorine.

The combinations of peroxide of copper with phosphoric, carbonic, and other acids, are effected by adding to a solution of nitrate or sulphate of copper, a solution of a neutral salt, containing the acid with which the copper is designed to be combined. The carbonate, phosphate, and borate of copper, are in the form of precipitates of a green colour, more or less deep. The fluuate of copper can be crystallized. Copper is slowly oxidated by a num-



ber of weaker acids, as by sour vegetable juices, when acted on by them with the admission of air. Acetic acid or vinegar, in particular, forms several compounds with oxide of copper: to obtain these, copper plates are exposed to the fumes of acetic acid; a crust is soon formed of a green colour, which is the verdigris of commerce. The composition of this salt has been ably investigated by Mr R. Phillips. Common verdigris, he has shown, consists essentially of minute blue crystals, which are the proper acetate of copper, composed of one atom of peroxide of copper, 80, one of acetic acid, 50, and six of water, 54, = 184. When verdigris is dissolved in acetic acid, the solution on evaporation affords prismatic crystals of a rich green colour, which consist of two atoms of acid, 100, one atom of peroxide of copper, 80, and three atoms of water, 27, = 207; this salt, then, is a binacetate of copper. In dissolving common verdigris in water, it is resolved into the binacetate, which exists in the solution; and an insoluble powder of a light green colour, which Mr Phillips found to be a subacetate of copper, containing two atoms of base to one of acid.

All the salts of copper are decomposed by the alkalis and earths. Potash, soda, and the alkaline earths, throw down precipitates, which are of various shades of green or blue, according to the quantity of alkali added, the colour being green if a small quantity has been employed, and becoming blue from a larger quantity. These precipitates are sub-salts, the alkali attracting the greater part of the acid, but the oxide precipitated retaining a portion of the acid combined with it.

The action of ammonia on the salts of copper is more peculiar. It first abstracts a portion of the acid, and throws down a green or blue precipitate, which is a sub-salt. But if added in larger quantity, it re-dissolves this



precipitate, and forms a transparent solution of a very deep blue colour. It also dissolves the pure oxides of copper directly, forming a similar blue solution with the peroxide; but with the protoxide the solution is colourless, as is shewn in the experiment of inclosing copperfilings with the blue solution in a phial closely stopped; the colour is gradually removed by the metallic copper abstracting a part of the oxygen of the dissolved oxide; while the blue tint almost immediately appears at the surface of the liquid when the air is admitted. The ammoniuret of copper may be obtained by evaporation in fine blue crystals. A triple compound used in medicine under the name of Ammoniuret of Copper, is prepared by triturating two parts of sulphate of copper with one part of carbonate of ammonia, the mass becoming soft from the mutual action of the two salts, the carbonic acid being disengaged with effervescence, and the triple compound of sulphuric acid, oxide of copper, and ammonia, being obtained of a deep violet colour.

Copper is precipitated in its metallic state from its saline solutions by zinc and iron, these metals attracting the oxygen which serves as the medium of its union with the acid of the solution. Its oxide is precipitated by albumen, and the precipitate is almost inert: hence the whites of eggs have been recommended as an antidote to the poisonous salts of copper.

Copper and sulphur unite by fusion, the combination being attended with an evolution of heat and light. Copper leaf, heated in the vapour of sulphur, burns brilliantly. The compound is of a dark grey colour, with semi-metallic lustre, agreeing in every respect with the native black sulphuret; it consists of an atom of copper, 64, and one of sulphur, 16, = 80. A bi-sulphuret of copper also exists in copper pyrites.



Copper combines with the greater number of the metals by fusion: according to Mr Dalton, its alloys are of definite constitution. It communicates hardness to gold and silver, without much diminishing their ductility, or debasing their colour, when in small proportion; hence it is employed in the standard alloys of these metals, that of gold containing one-twelfth, that of silver one-sixteenth of the mass. With platina it forms an alloy, ductile, and susceptible of a fine polish. Quicksilver easily amalgamates with it, and in small quantity renders it brittle. With zinc it forms brass and pinchbeck; with tin, bell-metal and bronze.

Copper, from its comparative fusibility, its ductility, the facility with which it can be extended in sheets, and with which it can be united by solder, is capable of being applied to many purposes of utility; and it is accordingly employed in the construction of boilers, stills, and various household utensils. Its utility for these purposes is much limited by its poisonous quality; this has been attempted to be obviated by coating its surface with a thin layer of zinc or tin, and this, besides the mechanical protection it gives, by rendering the copper negatively electrical tends greatly to prevent its oxidation and solution: the precaution, however, is scarcely effectual, as the vapour of acetic acid is found to corrode the surface of copper wherever it is exposed, even though the rest of it may be covered by these metals. In general, it is found, that sour vegetable juices scarcely dissolve any of the copper vessels in which they are contained if they are warm, so that the atmosphere of steam excludes the atmospheric air; but if allowed to cool in such vessels, poisonous salts of copper are formed. In thin sheets, copper is applied to sheath the bottoms of ships, and for this purpose is preferable to any other metal. Several of its combina-



tions are used as pigments, and some are employed in the practice of medicine.

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## CHAP. X.—OF IRON.

THIS is the most extensively diffused of the metals. It exists in the mineral kingdom in large quantity, and under numerous forms; it is a constituent principle of vegetable matter, and is obtained from the ashes of every plant; it exists in the blood, and other animal products; it is even an atmospheric or meteoric production, those stony masses which at different times, and in different countries, have fallen from the atmosphere, containing iron as their principal ingredient.

The ores from which iron is extracted, are those in which it is mineralized by oxygen; of which there are many varieties, consisting of the oxide intermixed with argillaceous, calcareous, and siliceous earths. It is principally from the argillaceous ore, or clay iron-stone, that iron is extracted in this country. The ore is roasted to expel any foreign volatile matter; it is then put into a furnace with layers of coaked coal, and with a quantity of lime, and is exposed to an intense heat excited by a blast of compressed air. The lime combining with the other earthy substances in the ore, they vitrify more easily, so as to admit of the action of the carbonaceous matter of the coal on the oxide, and the separation of the metal reduced by the abstraction of the oxygen. The charge of fresh materials is renewed at the upper part of the furnace, and the process is carried on without interruption, the vitrified matter being withdrawn by an opening in the



side, and the melted metal run out at the bottom. It forms what is named crude iron, pig iron, or cast iron.

In this state it is not the pure metal ; it always contains a portion of carbon, and it has also been supposed of oxygen ; and frequently smaller portions of other ingredients, manganese, silix, or, according to Berzelius, silicium, alumina, phosphorus, and chrome. The oxygen, carbon and phosphorus, appear to be diffused through the metal in the state of oxide, carburet, and phosphuret of iron. Mr Dalton, however, has lately estimated the quantity of carbon in cast iron at not above 2 *per cent.*, and of oxygen at 1 *per cent.* \*. According to the nature and proportions of the foreign substances in it, the qualities of iron are modified. Three principal varieties have been distinguished ;—white crude iron, of a striated fracture, and brittle ; grey crude iron, having a granular fracture and less brittle than the other ; and, lastly, the black crude iron, which is of a dark grey colour, approaching to blue, and the fracture of which presents larger granular concretions ; it is also softer and more fusible than the others. The chemical distinctions between these have not been well ascertained ; the first is supposed to contain more oxygen, the second oxygen and carbon, and the third a larger quantity of carbon. The production of them depends on the proportion of fuel to the ore in the process of reduction, and partly on the nature of the ore itself.

Crude iron in all its varieties is much more fusible than pure iron ; hence it can be cast into a variety of forms ; it is at the same time more hard and brittle, and is therefore unfit for many of the purposes to which the other is applied.

To obtain pure iron, crude iron is submitted to two ope-

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\* Chemical Philosophy, vol. ii.



rations, fusing and forging. In melting it, part of the foreign matter separates and collects on the surface; and if kept in fusion for some time, the separation is rendered more perfect, a blue lambent flame appears on the surface, apparently from the disengagement of carbonic oxide, or carburetted hydrogen; and the metal, at first liquid, gradually becomes thick and viscid from its fusibility diminishing, and at length assumes the consistence of a paste; it is then submitted to the action of the forge-hammer, or to the pressure of steel-rollers, by which a quantity of oxide of iron and other impurities is forced out. In this state it forms forged or bar iron, which is no longer granular, but fibrous in its texture; is soft, ductile, and malleable, and much less fusible; it is the metal in a nearly pure form.

Still there are some peculiarities in forged iron, giving rise to different varieties. One kind of forged iron, instead of being equally ductile and malleable at all temperatures, has this ductility, when cold, but is brittle at a high temperature; this is named hot short iron: another, named cold short iron, has the opposite property, being ductile and malleable when heated, but brittle when cold. The causes of these peculiarities are not well determined. The cold short property appeared, from Bergman's experiments, to depend on the presence of a substance which he named Siderite, afterwards ascertained to be phosphuret of iron. The hot short property has been ascribed to sulphur, arsenic, manganese, or chrome.

Forged iron, free from these peculiarities, is the metal in its pure state; its texture is fibrous; its colour a light grey, accompanied in the fresh fracture with considerable lustre; its specific gravity is 7.7; in hardness it is superior to the greater number of the metals; it also exceeds them in ductility, being capable of being drawn into wire much finer even than a human hair, and having such te-



nacity that a wire of 0.078 of an inch in diameter supports, without breaking, above 500 pounds. It is also highly elastic.

Iron is distinguished by the property of magnetism; it has even been supposed to be the only substance which possesses it; some other metals, however, particularly nickel, chrome, and cobalt, appear also to be magnetic. The magnetic power remains within a certain degree of oxidation, that forming the black oxide, but beyond this is impaired; it also remains when the iron is combined with a certain proportion of carbon, sulphur, or phosphorus, but past this it is weakened, and at length destroyed.

Iron is extremely infusible, and was supposed to be incapable of being melted by any heat that can be excited in a furnace. Its fusion has been accomplished, however, at a temperature calculated to be about 160° of Wedgwood's scale. Crude iron melts at 130°. At a temperature far below that which is necessary to its fusion, forged iron softens until its surface appears as if it were covered with a thick tenacious fluid; and this softening extends so far through the whole mass, that two pieces in this state hammered together unite firmly. This is the property of *welding*, so valuable with regard to iron, as rendering it capable of being worked; it is possessed besides only by platinum, and by it in a very inferior degree. The temperature at which it takes place is about a white heat; if the temperature be raised much beyond it, the iron becomes brittle, and falls to pieces under the hammer.

Iron is oxidated by atmospheric air. Even at a common temperature it undergoes the operation of rusting, in which it is oxidated. This change, however, depends partly on the agency of water, as it is accelerated by humidity; and if the air is perfectly dry, it scarcely takes place. The rust is not a pure oxide, but contains carbonic acid, absorbed from the atmosphere.



When iron is raised to a low red heat, it assumes various tints of colour from oxidation, and at length scales form upon it, consisting of the oxide. In the state of filings, it burns brilliantly when projected across the flame of a burning body, and ignited iron-wire burns with splendour in oxygen gas. The black oxide of iron thus formed is not the pure protoxide, which is described as of a blue colour, obtained by passing hydrogen gas over the peroxide, and inferred to consist of one atom of iron, 28, and one of oxygen, 8, = 36. If this oxide be heated in the air, it changes its colour and becomes the red oxide or peroxide, which appears to be composed of one atom of iron, 30, and one and a half of oxygen, 12, = 42. 40 These oxides are obtained also by other processes. The black oxide is produced by the slow action of water on iron, when the iron is entirely immersed in it; and also in the more rapid decomposition of water, when it is transmitted over the metal at a red heat. The true protoxide exists in several of the saline combinations of iron: the red oxide is the base of those at a high state of oxidation, and is obtained from their decomposition. Other oxides, with different proportions of oxygen, have been stated on the authority of different chemists; these are usually regarded as compounds of the protoxide with the peroxide: thus an oxide obtained by Gay-Lussac, by passing steam over red hot iron, is considered to be composed of one atom of protoxide of iron, 36, and two of peroxide, 80, = 116. Dr Thomson conceives this oxide to exist in Prussian blue. There is even an anomaly with regard to the protoxide and peroxide of iron, that their composition does not accord with the law of simple multiples being observed in the degrees of oxidation. The second proportion of oxygen is not as 2 to 1, or 3 to 1, but as  $1\frac{1}{2}$  to

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2. 4. This difficulty, as has been before explained, may be obviated by doubling the numbers, which will give two atoms of oxygen in the black oxide, and three in the peroxide, and, supposing the existence of a third compound, the real protoxide, of one atom of iron and one of oxygen. To this explanation it is objected, that this first oxide has not been discovered, though on the atomic theory it ought, as the simple binary compound, to be more easily obtained than any other. Another view is regarded by many as the more probable one, that the peroxide consists of two atoms of iron and three of oxygen; in this case its equivalent will be 80. The disadvantage of this, and of the common opinion, that the peroxide contains an equivalent and a half of oxygen is, that most of the salts of iron must be considered as sesqui salts. None of the oxides of iron can be reduced by heat; but their reduction is accomplished by the action of carbonaceous matter at a temperature sufficiently elevated.

Iron is oxidated and dissolved by the acids with facility; its saline compounds, when neutral, are in general soluble and crystallizable.

Sulphate of iron is a salt which has long been known under the name of Green Vitriol. It is economically prepared from the native sulphuret of iron, which, when calcined, and exposed for some time to air and humidity, absorbs oxygen, so that the sulphur is converted into sulphuric acid, and the iron is oxidated; the sulphate of iron, thus formed, is extricated by lixiviation and crystallization. This proto-sulphate, or Green Sulphate of Iron, is obtained more pure by the direct solution of iron in diluted sulphuric acid, the acid enabling the iron to decompose the water by attracting its oxygen, and at the same time combining with the oxide. The solution is of a pale green colour, and, if concentrated, affords green crystals, in the



form of rhomboidal prisms, soluble in two parts of cold water. They consist of one atom of protoxide of iron, 36, one of acid, 40, and seven of water, 63, = 139. Exposed to heat, this salt liquefies: when the water of crystallization is dissipated, it forms a dry mass of a greenish colour; when urged by a strong heat, the greater part of its acid is expelled, partially decomposed, and a red oxide remains. Exposed to the air, it loses its transparency, and is covered with a yellowish crust, a change owing to the absorption of oxygen. This absorption takes place to a greater extent when the salt is in solution, and continues until the oxide pass to the maximum of oxidation. As the peroxide thus formed requires a larger quantity of acid for its saturation than the protoxide in the green sulphate does, a portion of it is precipitated, while the remaining quantity is retained in combination with the acid, forming the Red Sulphate of Iron: it is also termed a persesqui-sulphate of iron, as containing an atom and a <sup>or rather</sup>  $\frac{1}{2}$  of acid, 60, to one atom of peroxide of iron, 40, =  $\frac{120}{80} = 2$  100. It is not crystallizable, but when its solution is evaporated it forms a mass of a yellowish-red colour: it is soluble in alcohol, and this affords a mode of separating it from the other. With re-agents, these salts afford different phenomena. The green sulphate, decomposed by the alkalis, gives precipitates of a green colour; the red sulphate affords precipitates of a yellow colour, approaching more or less to red; the former, with triple prussiate of potash, gives a white precipitate; the other, with the same test, a precipitate of a very deep blue colour; the one is little altered by the infusion of galls, the other strikes immediately a deep purple colour.

Sulphate of iron is applied to numerous uses in the arts, more particularly in dyeing, as forming, with vegetable astringents, the bases of black dyes, and, with other co-



louring substances, different shades of colour. Its combination with these astringents is the basis of writing ink.

Sulphurous acid dissolves iron, being partly decomposed, so that the combination is a sulphuretted sulphite of iron, or rather a hypo-sulphite of iron. The pure sulphite is obtained by the direct combination of the acid with oxide of iron; it is soluble in water; it is not coloured by galls.

Nitric acid is decomposed by iron with rapidity, the peroxide is formed, and a persesqui-nitrate of iron results. When the acid is diluted, the action is more moderate, and a more perfect solution is obtained. By evaporation in vacuo, Dr Thomson obtained the proto-nitrate in rhomboidal prisms of a light green.

Muriatic acid dissolves iron with facility, the iron receiving oxygen from the water, and the solution being therefore attended with a disengagement of hydrogen gas. The liquor is of a pale green colour, and affords crystals by evaporation of the same colour. If oxide or rust of iron is dissolved in muriatic acid, a solution is obtained of a yellow colour, which does not crystallize on evaporation, but affords a soft deliquescent mass. In the one of these salts protoxide, in the other peroxide of iron exists; hence they differ in their chemical properties; the former, the green muriate, is insoluble in alcohol, is little altered in its colour by infusion of galls, and, when decomposed by the alkalis, gives a green precipitate; the latter, the red muriate, is soluble in alcohol, gives a deep purple colour with galls, and a blue with prussiate of potash, and affords a yellow precipitate when decomposed by the alkalis. The green is converted into the red muriate by exposure to the air: when obtained dry by evaporation out of contact of the air, it is a chloride of iron; this is of a dark green colour, which, in certain positions, appears grey, with



considerable lustre: it is inferred to consist of one atom of chlorine, 36, and one of iron, 28, = 64. The perchloride is obtained by burning iron wire in chlorine gas: it is of a bright yellowish brown or reddish colour, with considerable lustre, volatile, and soluble in water, becoming the red muriate of iron; it consists, like the peroxide, of an equivalent and a half of chlorine, 54, and one of iron, 28, = 82. *164* *3 of chlorine* *108* *2*

Iron is acted on by water strongly impregnated with carbonic acid, and a portion of it is dissolved. The common rust of iron contains a portion of this acid; and a true carbonate of the protoxide exists native. The sub-carbonate used in medicine is formed by decomposing sulphate of iron by carbonate of potash or soda; it is precipitated of a greenish colour, but in drying becomes brown from absorption of oxygen from the air. It contains about 15 *per cent.* of carbonic acid, and a large quantity of peroxide of iron.

Phosphoric acid acts weakly on iron; but the phosphate may be formed by adding phosphate of soda to a solution of persulphate of iron: it is of a white colour, insoluble in water, and fuses into a brilliant globule by intense heat. Prussic acid has a powerful affinity to oxide of iron. When the triple prussiate of potash and protoxide of iron is added to solutions of the proto-salts of iron, a precipitate of a light blue colour is thrown down, which, by exposure to the air, or the action of any substance capable of communicating oxygen, becomes of a deeper hue, forming the pigment of a rich blue colour known by the name of Prussian Blue. The nature of this substance is even at present imperfectly understood; indeed, there is perhaps no chemical compound respecting which there is such uncertainty. It was at one time regarded as a cyanide of metallic iron; but there appears sufficient rea-



son for inferring the iron to be oxidated. The metal is commonly supposed to be in the state of peroxide; but Dr Thomson is rather of opinion that it is Gay-Lussac's intermediate oxide which exists in it. On Mr Porret's view, Prussian blue is a ferro-cyanate of peroxide of iron. Berzelius regards it as a compound of prussiate of protoxide of iron with peroxide of iron; or it may be called a double prussiate of protoxide of iron and peroxide of iron. From the deepness of the colour of this combination, the triple prussiate of potash and iron affords one of the most delicate tests of iron. Gallic acid produces with the salts of iron, in the higher degrees of oxidation, a deep violet tinge, and in the state in which it is combined with tannin in the infusions of vegetable astringents, particularly of galls, is a test still more delicate and more accurate. Succinic acid forms with peroxide of iron an insoluble brown compound, and from this property, is much employed in delicate analyses, to ascertain the quantity of iron which may be present in any saline solution. The brown precipitate is heated to destroy the acid, and is then exposed to heat mixed with a little linseed oil, which reduces it to the state of protoxide; 100 grains of this contain 77.7 of metallic iron. Benzoic acid has a similar effect, and being less expensive than succinic acid, has been employed under the form of benzoate of ammonia.

Iron appears to exert a strong attraction to carbon. When melted from its ores in contact with the fuel, a portion of carbonaceous matter combines with it, and this, with oxygen and other ingredients, forms cast iron. The combination of iron with carbon alone, constitutes Steel, one of the most useful forms of this valuable metal.

The usual process for forming steel is that named Cementation, in which bars of malleable iron are imbedded



in layers in charcoal powder in a close furnace, through which flues are carried to distribute the heat: a strong fire is applied for six or eight days; the progress of the cementation is known by withdrawing a bar from the furnace: if this is sufficiently changed, the fire is extinguished, and the metal is left to cool for six or eight days. This forms Blistered Steel; it is rendered more perfect by subjecting it to the operation of the forge-hammer, as in forging iron; or by welding it; or it is fused with the addition of a little charcoal, and cast into small bars, forming what is named Cast Steel. These operations are performed on malleable iron; but some kinds of cast iron, particularly the grey crude iron, can be converted into steel of an inferior quality by a similar process. Steel is also formed by fusing forged iron with charcoal.

In this operation, an increase of weight from  $\frac{1}{180}$ th to  $\frac{1}{140}$ th is gained. The more carbon is introduced, the more brittle is the steel. Bergman first clearly shewed the presence of this carbonaceous matter, by ascertaining by experiment, that less hydrogen is disengaged during the solution of steel in diluted sulphuric acid, than during the solution of iron in the same acid; and that, during the solution of the steel, carbon is precipitated in the form of a black shining powder, similar to plumbago. Guyton has observed, that it is probably pure carbon, not charcoal, that is present in steel; and to this its great hardness may be ascribed. This has been confirmed by the experiment of converting iron into steel, by exposing it to heat with diamond. Mr Dalton, however, has lately maintained the singular opinion, that steel contains little or no carbon, and that its peculiar properties are merely owing to a species of crystalline arrangement of its particles\*. The presence of carbon in steel is proved both by

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\* Chemical Philosophy, vol. ii. p. 217.



its being necessary to the conversion of iron into steel, and by the simple experiment of letting a drop of acid fall upon steel, when the surface will immediately be blackened, by the iron being dissolved, and the carbon liberated. Bergman found, that some specimens of steel contain manganese and silex; and Vauquelin has likewise discovered the existence of silex, or perhaps rather its metallic base, and of phosphorus, in several kinds of steel which he analysed.

Steel is of a grey colour; when heated it assumes various brilliant colours on its surface from oxidation; its fracture is granular and brilliant, and it is susceptible of a high polish. It is more fusible than iron. It is ductile and malleable, and when hammered, its ductility and its elasticity are increased. The property by which it is eminently distinguished is, that of acquiring a great degree of hardness by being immersed in cold water when previously heated, the hardness being greater as the steel has been hotter and the water colder; it at the same time becomes more brittle and elastic, effects which evidently arise from the irregular aggregation produced by the sudden cooling. Steel, thus hardened, may have its softness and ductility restored, by again heating it, and allowing it to cool slowly. This is what is termed *tempering* it, the requisite degree of *temper* being given by heating the metal more or less, previous to the slow cooling. The harder steel is, it is also the more elastic, and at the same time more brittle, and hence, for different purposes, different degrees of this quality are required. Steel possesses a degree of hardness superior to any other metal; it is also possessed of the highest elasticity; and from these properties it acquires its high value. Some alloys of steel with different metals have been formed by Messrs Stodart and Faraday, which appear to possess valuable



qualities. The alloy of steel, with one-hundredth of its weight of platina, possesses along with all the hardness of steel a much greater degree of toughness, which renders it fitter for a number of purposes. The alloy of steel with silver is remarkable for its hardness, surpassing in this respect even the Indian Wootz. The alloy of steel with rhodium would be one of great utility, if the latter metal were not so scarce and expensive; it is conceived that this, from its brilliant lustre, and power of resisting oxidation, would form the best material for metallic mirrors. The alloy of steel with chrome likewise possesses very valuable properties.

The mineral substance known by the name of Plumbago, or Graphite, is a compound of iron and carbon. The proportion of iron is variable, but in general does not exceed from 3.5 to 10 in 100 parts. By exposure to a continued red heat, the carbonaceous matter is slowly consumed, being converted into carbonic acid, and oxide of iron remains. It suffers a similar change by deflagration with charcoal. It is scarcely acted on by the acids. From its softness and lubricity, plumbago is used to lessen the friction of machinery; it is added to some kinds of earthen ware, to communicate a degree of tenacity, whence the composition is not so liable to crack on exposure to heat. It is rubbed on the surface of iron to prevent rusting, and it forms the best kind of black crayons. Plumbago appears, from the statements of Dr Macculloch, to exist often in large proportion in cast iron: under particular circumstances, indeed, masses of cast iron are changed almost entirely into plumbago. When the surface of this is scraped, it frequently becomes extremely hot, probably from the oxidation of silicium present in the mass. The retorts used in making oil gas have also been found, after some months, to be partially converted into plumbago.



Iron has a strong attraction to sulphur, and combines with it with facility by fusion, the combination being attended with the evolution of heat and light: this is the proto-sulphuret, consisting of one atom of iron, 28, and one of sulphur, 16, = 44. It is distinguished by the property of being magnetic: it exists in nature, and is called Magnetic Pyrites. The abundant mineral named Iron Pyrites, is a bi-sulphuret of iron, or composed of one atom of iron, 28, and two of sulphur, 32, = 60. These compounds are of a grey or yellow colour, frequently variegated, with a degree of lustre, the colour approaching more to yellow, and the lustre being more perfect, as the proportion of sulphur is large. They are of a crystalline texture, brittle, fusible, and are partially decomposed by heat. The proto-sulphuret, when moistened and exposed to the air, absorbs oxygen, and is gradually converted into sulphate of iron. A mixture of iron-filings and sulphur moistened acts on atmospheric air in a similar manner, and suffers the same change: and if a large quantity of it is employed, acts with such energy as to be inflamed. The alkaline sulphurets combine with iron by fusion, and also by boiling with water. Sulphuretted hydrogen, and the hydro-sulphurets, form precipitates from the salts of iron.

Iron combines with various metals, but its alloys are of little importance: that with copper is brittle, and of a grey colour. The principal alloy of any use is that with tin, forming what is named Tinned Iron, which is prepared by dipping iron plates previously cleaned by a diluted acid into melted tin.

Iron is perhaps the most useful of the metals, possessing in its pure form the highest degree of tenacity, ductility, elasticity, and hardness, whence it is applied to all purposes where strength is required; and though almost in-



fusible, it is capable, by the operation of welding, of being easily fashioned and worked. Cast iron, being fusible, can be adapted to other purposes, and derives value from its hardness, and from being less liable than forged iron to be acted on by the air. And the elasticity and hardness of steel adapt it to numerous uses, for which other metals would afford very imperfect substitutes.

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CHAP. XI.—OF TIN.

**T**IN has a white colour, with a slight shade of grey; it has little ductility, but so much malleability as to be capable of extension into thin leaves; it is soft and flexible. It is one of the lightest of the metals, its specific gravity being not more than 7.9. It occurs in nature in the state of oxide, and in smaller quantity in that of sulphuret, and is one of the metals of least extensive distribution, being found in few countries. Cornwall in England affords the largest quantity of it, and has done so from very early times. It is extracted from the native oxide by fusion in contact with the fuel, the oxygen of the ore being abstracted by the carbonaceous matter.

Tin is one of the most fusible of the metals, its melting point being not higher than  $442^{\circ}$ . By slow cooling it crystallizes in rhombs. When in fusion, if it is exposed to the atmospheric air, a film quickly forms on its surface, and a grey powder accumulates; this is the protoxide, consisting of one atom of tin, 58, and one of oxygen, 8, = 66. If this be longer exposed to heat, and stirred, it becomes the peroxide of tin, of a yellowish-white colour; when tin is exposed to a high heat, it burns with a weak flame, also forming the peroxide; this is composed of one atom



of tin, 58, and two of oxygen, 16, = 74. These oxides are also obtained by the decomposition of the salts of tin: from the solution of the metal in muriatic acid, a white precipitate is thrown down by potash, which is a hydrated oxide, and which becomes grey when the water is expelled by heat. By digesting the grey oxide with nitric acid, or by decomposing the nitrate of tin by an alkali, the peroxide is obtained. Berzelius supposes also the existence of an intermediate oxide, the base of the concentrated muriate of tin; this, however, is doubtful. All the oxides of this metal are reduced with facility by exposure to a sufficient degree of heat in mixture with carbonaceous matter. They are extremely fusible, but vitrify with earthy substances.

Tin loses its lustre from exposure to the air, but is not liable to rust. It suffers little change from the action of water at any temperature. Tin is oxidated and dissolved by the acids; and in these combinations is displayed one of the most characteristic properties of this metal, the avidity with which it combines with oxygen, and its tendency to pass to a highly oxidated state, so that the compounds at the *minimum* of oxidation are not easily obtained.

When heat is applied to favour its action on sulphuric acid, the acid is decomposed, and to that extent, that not only is sulphurous acid disengaged from the partial abstraction of oxygen, but from its entire abstraction sulphur is produced. The solution deposits slender crystals; it is decomposed by the effusion of water, and suffers even spontaneous decomposition when kept for some time, the oxide passing gradually to the state of peroxide, when it exerts a less energetic action on the acid. Sulphurous acid is also decomposed by tin; a portion of sulphuret of tin appears to be formed, and sulphite of tin is partly precipitated, partly retained in solution.



Nitric acid, in its most concentrated state, exhibits the same singular phenomenon with tin that it does with some other metals ; it is not decomposed by the metal, nor does it produce on it any change. But if somewhat weaker, or if a little water is added, the mutual action is rapid and violent, dense vapours of nitrous acid are disengaged, and the tin is so highly oxidated, that it is not dissolved, and appears scarcely to be combined with any of the acid. If the acid is more largely diluted, a more perfect solution is obtained, though still attended with the abundant disengagement of nitric and nitrous oxides. Such is the avidity even of this metal to oxygen, that the decomposition of part of the acid is complete ; the water is at the same time decomposed by the abstraction of its oxygen, and the nitrogen of the one and hydrogen of the other being evolved, are presented to each other in their nascent state, unite and form ammonia, with which a portion of the acid combines. The solution of the nitrate is not permanent, the tin continuing to attract oxygen from the acid, and the peroxide being deposited.

Muriatic acid is the proper solvent of tin : it dissolves it in the cold, but more rapidly when heat is applied, hydrogen gas being disengaged. The proto-muriate of tin formed consists of one atom of protoxide of tin, 66, and one of muriatic acid, 37, = 103. Its solution deposits, when concentrated, needle-like crystals, which are somewhat deliquescent ; they are not dissolved in water without being partially decomposed, and submuriate of tin precipitated. The protoxide in this combination has a great tendency to pass to the state of peroxide ; and in consequence of this, this solution acts with energy on a number of the compounds of oxygen, particularly the metallic salts, decomposing them partially, or in some cases completely, by attracting oxygen. It attracts oxy-



gen, too, from several of the acids, and absorbs it from the air.

By heating an amalgam of tin and mercury with calomel, Chloride of tin is formed, which, when dissolved in water, becomes the protomuriate. The Bi-chloride of tin, or, as it was formerly supposed to be, a bi-muriate of peroxide of tin, is a fluid possessed of some very peculiar properties. The process long known to chemists by which it is obtained, consists in exposing to heat a mixture of an amalgam of tin and quicksilver with corrosive sublimate; the two proportions of chlorine are transferred from the quicksilver to the tin, and the bi-chloride of tin is obtained by distillation. It is a dense liquid, known by the name of Liquor of Libavius, which exhales white vapours when exposed to the atmosphere, from combining with the watery vapour of atmospheric air: their odour is acrid; the liquid, on being presented to water, combines with it with a hissing noise, and the disengagement of an elastic fluid. When combined with about one-third its weight of water, it forms a solid mass, which melts on the application of heat, and congeals by cold. The same compound is formed by passing a current of chlorine gas through a solution of muriate of tin, and expelling the excess of acid by heat; or by heating tin gently in chlorine gas.

Nitro-muriatic acid dissolves tin with great rapidity: to obtain a proper solution, it is even necessary that the action should be moderated by dilution with water, and by adding the metal in successive portions; otherwise it is so highly oxidated, as scarcely to enter into combination with the acid. The solution, when concentrated, soon acquires a gelatinous consistence, and at length becomes concrete. The affusion of water decomposes it, and precipitates the oxide, which remains diffused through the liquor, rendering it white and opaque. This solution is an important



mordant in the art of dyeing, rendering several colours, particularly scarlet, more brilliant and permanent; but there is considerable difficulty in preparing it uniform, from the tendency of the metal to become highly oxidated.

The alkalis unite with oxidated tin; when employed to decompose the salts of tin, they re-dissolve the precipitate when added in excess. The ternary compounds of oxide of tin, with portions of acid and of alkali, are even capable of crystallizing. The alkalis dissolve likewise the oxide, independent of the presence of any acid,—exerting, in conformity to the law already stated, the strongest attraction to the metal in its more highly oxidated state. Some of these combinations likewise crystallize \*.

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\* From their thus combining with alkalis, the oxides of tin have by some been regarded as acids, and it has even been proposed to place them in that class of compounds. This proposal is in conformity with the practice which has so much prevailed of late years, to the overthrow of true chemical distinctions, of ranking every substance as an acid which forms combinations with a few oxidated bases. This unphilosophical principle, of selecting one of the characters of acidity as a criterion to the exclusion of every other, has, as might have been expected, led to the most direct violations of chemical analogy. Silica, for instance, one of the most inert of substances, and one of the most remote certainly in all its properties from those agents which have so long been known under the name of Acids, has yet been included in that class. Even alumina has been regarded as performing the part of an acid. The *antimonious*, *antimonic*, *manganesious*, *manganesic*, *auric acids*, and various other metallic oxides of no greater energy, are associated by this nomenclature with the powerful sulphuric, nitric, and other mineral acids. Nay, so far has this confusion of terms been carried, that the compounds of oxide of lead, for example, with gum and starch, have been called *gummate* and *amylate* of lead. There is, indeed, no limit to the number of bodies which,



Tin and sulphur unite easily by fusion : the proto-sulphuret is of a grey colour with metallic lustre, and may be obtained crystallized in cubes ; it consists of one atom of tin, 58, and one of sulphur, 16, = 74. A bi-sulphuret of tin also may be formed ; it is a compound of a golden colour and lustre, and flaky appearance, named *aurum musivum*, and sometimes used for ornamental purposes. The process usually followed to obtain it is to melt 12 parts of tin in a crucible ; adding, as it cools, 3 parts of quicksilver, and completing the amalgamation by trituration. This is then intimately mixed with 7 parts of sulphur and three of muriate of ammonia : the mixture is exposed to heat in a matrass as long as any white vapours are disengaged : the heat is then raised to redness, a little sulphuret of mercury and muriate of tin sublime, and the *aurum musivum* remains at the bottom of the matrass. It used to be regarded as a sulphuret of oxide of tin, but, according to Dr J. Davy and Berzelius, it is strictly a bi-sulphuret of metallic tin.

With the greater number of the metals tin combines

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on this principle, may be included in the class of acids, as there is scarcely an oxidated substance with which we are acquainted, which does not combine with some other oxides. Even the alkalis themselves ought, on this view, to be placed among the acids, forming much more numerous and intimate combinations with bases, than the oxides of tin, or of gold, or various others which are at present so denominated. The principal characters of acids, it has been already stated, are, that they are sour to the taste, change the blue, purple, and green colours of vegetables to a red ; have, in general, a considerable affinity to water, and combine readily with it ; dissolve the metals, imparting oxygen to them directly, or by the medium of other substances ; and form neutral compounds with bases. No metallic oxide will in the text be termed an acid, but what exhibits these properties in a certain degree. ED.



with facility, and several of its alloys are in common use. It had always been believed, that in combining with gold it destroys its ductility, though present even in the most minute quantity. From the experiments of Alchorne, this appears to be a mistake; and it had probably originated from the operation of some of the other metals, which the tin of commerce contains in small quantity. It combines with platina, forming a brittle and fusible alloy. It amalgamates easily with quicksilver; when the proportion of quicksilver is only one-fifth, the alloy is solid and capable of crystallizing: amalgam of tin is used as a covering to glass mirrors, to enable them to reflect the light, and glass globes are sometimes coated internally by a similar amalgam. With copper, tin forms a series of valuable alloys, —bronze, bell-metal, and others. Bronze is the one in which the proportion of tin is smallest; it does not exceed 10 or 12 parts in 100; it is harder than copper, less liable to rust, and when melted, flows thinner, and therefore takes a more delicate impression from a mould; hence its adaptation to the fabrication of statues and ornamental vessels. The metal of which pieces of artillery are cast is of a similar composition. An alloy nearly of the same composition was in use among the ancients, for the fabrication of swords, darts, and other warlike instruments. Dr Pearson having analysed different ancient instruments of this kind, found the composition to be eight or nine parts of copper with one of tin; and from its hardness it affords, as he remarks, the best substitute for iron or steel. Of the same alloy ancient medals and coins appear to have been often formed. When the proportion of tin is larger, the alloy becomes more brittle; it is also highly sonorous; it then forms bell-metal. The Chinese gong-metal is of a similar composition, containing about 20 of tin with 80 of copper. With the tin considerably



increased in quantity an alloy is formed nearly white, of a close texture, susceptible of a fine polish, and not liable to tarnish, and, from these qualities, well adapted to the purpose to which it has been applied, that of forming the speculum of reflecting telescopes; the addition of a small portion of arsenic and zinc adds to the density and whiteness. The composition recommended from the latest experiments, those by Mr Little, is 32 of copper, 4 of brass,  $16\frac{1}{2}$  of tin, and  $1\frac{1}{4}$  of arsenic. Lastly, from the affinity between tin and copper, the latter metal can be covered with a thin layer of the former; this tinning of copper is executed by applying melted tin to the surface of the copper, clean and preserved from oxidation at the temperature to which it is raised by the application of muriate of ammonia, or of pitch; by this covering, the noxious impregnation which might be communicated from copper vessels to liquors boiled or preserved in them, is supposed to be prevented.

Tin and iron unite by fusion, forming alloys with properties varying according to the proportions. Plates of iron immersed in melted tin unite with it at both surfaces, forming tinned iron, which, in the fabrication of small vessels, has the advantage over iron of being more flexible, less liable to rust, and easily united by solder. Tin and lead, differing little in fusibility, can be united in all proportions. Pewter is an alloy of this kind, with the addition sometimes of a little copper and zinc. Equal parts of tin and lead form soft solder.

It is in the formation of these alloys that tin is principally employed. Its oxides are used in enamelling, and to polish the metals; and its solution in nitro-muriatic acid is a valuable mordant in the processes of dyeing.



## CHAP. XII.—OF LEAD.

**LEAD** is the softest and least elastic of the metals; it has little ductility, but considerable malleability; its lustre tarnishes speedily; its specific gravity is 11.3: when rubbed it has a peculiar smell; it has also a perceptible taste, and is one of those metals, the compounds of which prove most noxious to animal life. Its action too, as a poison, is very insidious, being liable to accumulate in the system, without immediately producing any sensible effect.

Lead occurs mineralized by carbonic, sulphuric, phosphoric and molybdic acids, and by sulphur. It is from the last of these ores, the Galena of mineralogists, that the greater part of the lead of commerce is extracted; the ore reduced to powder is mixed with lime, and exposed to heat; the lime combines with the sulphur, and the lead is run out. The other ores are previously roasted, and are heated in mixture with lime in contact with the fuel.

Lead melts at a temperature a little inferior to ignition, or about  $594^{\circ}$  of Fahrenheit. When cooled slowly, it crystallizes in aggregated pyramids.

When in fusion, it is oxidated with great facility by the atmospheric air; its surface is quickly covered with a film which increases, and a grey powder accumulates. This, by exposure to a higher heat, acquires a lively yellow colour, forming what is named Massicot, which is an impure protoxide. If the flame be made to reverberate on its surface, and it be constantly stirred, the colour changes to a bright red, and an impure deutoxide, named Minium, or Red Lead, is formed. By applying heat quickly to the yellow oxide, directing at the same time a current of air over its surface, it is semi-vitrified, and forms a yellowish substance in thin scales, named Litharge, which



contains a little carbonic acid. This, by a more powerful heat, may be completely vitrified, when it forms what is named the Glass of lead. The degrees of oxidation of lead then are three in number. The yellow protoxide, obtained pure by decomposing the nitrate by heat, is inferred by Berzelius to consist of one atom of lead, 104, and one of oxygen, 8, = 112. Minium is a mixture of protoxide and deutoxide. When this is purified, the red deutoxide is composed of one of lead, 104, and oxygen, 12, = 116. Lastly, by digesting this red oxide in nitric oxide, part of it becomes the yellow oxide, yielding an equivalent of oxygen to the rest, which thus becomes a brown peroxide; he found this to consist of one atom of lead, 104, and two of oxygen, 16, = 120: its high state of oxidation is shewn by its being insoluble in nitric acid, and its yielding oxygen when acted on by sulphuric acid. The proportions given by Berzelius are those of 1,  $1\frac{1}{2}$ , 2: if doubled, they give the proportions of 2, 3, 4: and this leads to the conjecture, that there exists a lower oxide containing a quantity of oxygen as 1, though this has not been obtained. All the oxides of lead have a considerable specific gravity: they are fusible, and act as powerful fluxes on earthy matter. The red oxide is partially decomposed by heat, giving out a portion of oxygen gas. It and the other oxides are easily reduced by heating them with carbonaceous matter.

Lead does not sensibly decompose water; but when kept immersed in water for some time, it is encrusted with a white substance, formed probably from the action of the oxygen which water holds dissolved. According to Guyton's experiments, the presence of a little neutral saline matter retards this oxidation, and hence it is less liable to happen with spring water than with distilled water, from the former containing sulphate or carbonate of lime.



Lead is oxidated by a number of the acids, and its oxides combine with them easily, when in a low degree of oxidation. When highly oxidated they previously part with a portion of their oxygen. Its salts, those of them at least which are soluble, are distinguished by a peculiar sweet and styptic taste.

Sulphuric acid has little action on it, even when aided by heat. The sulphate, formed by decomposing any of the soluble salts of lead by an alkaline sulphate, is inert and almost insoluble; hence soluble sulphates, as that of magnesia, have been recommended as antidotes to the poisonous salts of lead. It consists of an atom of yellow oxide, 112, and one of acid, 40, = 152.

Nitric acid acts more readily on lead, oxidating and dissolving it; the solution, by evaporation, affords small pyramidal crystals, white and semi-transparent, with adamantine lustre. They are composed of one atom of acid, 54, and one of yellow oxide, 112, = 166. They are converted, by boiling with a little of the yellow oxide, into a subnitrate, which forms in scales. Nitrous acid appears also to enter into combination with oxide of lead, forming both a nitrite and sub-nitrite. Muriatic acid, it is supposed, does not combine with oxide of lead: when a solution of muriate of soda is added to a solution of a salt of lead, a precipitate falls, which is regarded as a chloride of lead; this can be so far dissolved, however, by the aid of heat, as to afford, by evaporation of its solution, slender prismatic crystals, which are probably muriate of lead. The dry chloride melts at a moderate heat, and forms, on congealing, a solid semi-transparent mass, which, from its appearance, has been named Horn Lead. Chlorine gas, by its action on metallic lead, forms the same compound. Iodide of lead, formed by double decomposition, is of a rich yellow colour. It is soluble in boiling water. By



tritulating three or four parts of red oxide of lead with one part of muriate of soda moistened, the salt is completely decomposed, soda is liberated, and a sub-chloride of lead is formed, mixed with oxide of lead. When this is melted, it forms a pigment of a rich yellow colour, called *patent* or *mineral yellow*. This decomposition appears to be owing to the affinity of the oxide of lead to the acid, or of the lead to the chlorine, being aided by its quantity, a great excess of the oxide being used, and a sub-muriate or sub-chloride formed. The process was at one time carried on on a large scale, to obtain carbonate of soda from muriate of soda, the liberated alkali absorbing carbonic acid from the air, or from saw-dust burnt with it; cheaper methods, however, have now been discovered.

Phosphoric acid combines with oxide of lead, forming, when the combination is established by the exertion of a double attraction, a compound of very sparing solubility. Carbonate of lead, when it is formed by a similar process, is likewise insoluble. Cerusse, or white lead, is a carbonate. It is prepared by exposing plates of lead to the vapour of vinegar; a white crust forms on their surface from the oxidation of the metal, and the oxide either absorbs carbonic acid from the atmosphere, or the portion of this acid combined with it is formed from the partial decomposition of the vinegar. When cerusse is boiled with vinegar, it is dissolved, and by evaporation a salt is obtained in slender prisms aggregated, the sugar of lead of commerce, the acetate of lead.

Lead combines with sulphur by fusion, forming a compound of a dark grey colour and metallic lustre. The pure native sulphuret called Galena, consists of one atom of lead, 104, and one of sulphur, 16, = 120. Sulphuretted hydrogen tarnishes the lustre of lead, and it decomposes its saline compounds, forming a very dark co-



loured sulphuret of lead, the hydrogen of the sulphuretted hydrogen combining with the oxygen of the oxide, while the sulphur unites with the lead. The action of the hydro-sulphurets of the alkalis or earths is similar; hence these compounds, or the gas itself, afford the most delicate test to discover the presence of lead, and are sometimes employed to detect it where it is suspected to be present in wines or other liquors. The test is liable to some fallacies, however, from precipitating other metals, as iron, likewise of a dark colour: to prevent this, muriatic acid is added, as in the wine test of Dr Hahnemann, which is prepared by exposing equal parts of sulphur and oyster shells to a white heat for a quarter of an hour, adding to the sulphuret when cold, an equal quantity of cream of tartar, boiling the mixture for an hour in water, and, lastly, adding 20 drops of muriatic acid to every ounce of the test liquor. To avoid every chance of error, any precipitate obtained by adding it to wine ought always to be reduced. Or another method is to transmit sulphuretted hydrogen through the wine, to digest any precipitate that falls in nitric acid; to expel the excess of this acid by evaporation to dryness; then to dissolve it, and add hydriodate of potash, which will throw down a yellow iodide of lead, if that metal is present. From the deepness of the colour produced by the action of sulphuretted hydrogen on the salts of lead, solutions of these form a sympathetic ink, lines traced with any of them on paper becoming visible when exposed to the gas.

The alloys of lead which are of any use have been already noticed.

Lead is adapted to many purposes of utility, from its flexibility, the facility with which it is cast into different forms, and with which, when in sheets, it is united by solder. In thin sheets, it is employed for covering the



roofs of buildings. It forms evaporating vessels and boilers, to which the fire may be directly applied. And pipes formed of it are in common use for conveying water; an application which has been supposed to be not without danger, as lead suffers oxidation at its surface when immersed in water: in water conveyed through leaden pipes, however, no indication of the presence of lead can be discovered by the action of sulphuretted hydrogen; and from the perfect exclusion of the atmospheric air, the metal is probably little acted on by the water. The use of cisterns of lead for containing water must be more hazardous, as in these the metal is exposed to the action both of air and water; and they are probably rendered safe only from the deposit of earthy matter contained in spring water, which forms a crust covering the surface of the metal, and, if the experiments of Guyton already stated be just, from the saline and earthy matter retarding the oxidation. The oxides of lead are employed as pigments, and in the manufacture of the finer kinds of glass, to which they communicate density, and a higher refractive power. They are also used in glazing the coarser kinds of earthen ware, another practice not without hazard, as the glazing is acted on by liquors slightly acid. Several preparations of lead are employed in medicine, from their styptic power.

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#### CHAP. XIII.—OF ZINC.

**ZINC** is a metal which appears to have been discovered during the researches of alchemy. It exists in nature mineralized by oxygen, with or without carbonic acid, and by sulphur. From the first of these ores, the calamine of



mineralogists, it is extracted by a process founded on its volatility. The calamine calcined is mixed with charcoal powder; the mixture is put into conical pots closed at the head, a tube which rises nearly to the top within descending through the bottom, and terminating in a vessel of water beneath. A sufficient degree of heat is applied, the oxide of zinc is reduced, and the metal volatilized is condensed at the termination of the tube.

Zinc is of a bluish-white colour, accompanied in the fresh fracture with considerable lustre, but liable to tarnish from exposure to the air; its texture is striated; it is hard, and has a specific gravity of 7. It was usually considered as having little ductility or malleability; but it has been shewn by Mr Silvester, that at a certain temperature, it can both be drawn into wire, and extended in thin plates. The temperature at which this can be effected is between  $210^{\circ}$  and  $300^{\circ}$  of Fahrenheit; and by annealing it retains its tenacity when cold, so as to admit of being easily bent. At a higher temperature it is brittle.

Zinc melts nearly at ignition, and, when heated to a higher point, is volatilized unchanged. If the air is admitted to it when in fusion, its surface is covered with a grey oxide, and, if heated to ignition, the oxidation becomes rapid, and is attended with a vivid light, and considerable heat; an oxide is formed in light white flocculi, which are carried off by the rapid current of heated air from the surface of the burning metal. The oxide itself is not volatile, but vitrifies when urged by an intense heat, forming a transparent glass of a yellow colour. This, which is the only oxide of zinc, consists, according to Thomson, of one atom of zinc, 34, and one of oxygen, 8, = 42. It is not certain, however, that the atom of zinc is 34, the analysis of the sulphuret rather indicating it to be 33.



Zinc is scarcely sensibly acted on by water at a low temperature; but at a temperature approaching to ignition, it decomposes it, attracting oxygen.

It is oxidated and dissolved with facility by the greater number of the acids. Sulphuric acid, in its concentrated state, requires the aid of heat. When diluted it acts on the metal rapidly in the cold, enabling it to decompose the water present, and hence the solution is attended with a copious production of hydrogen gas. The solution, when concentrated, is of a thick consistence, and affords in a short time slender prismatic crystals of sulphate of zinc. This crystallized salt is soluble in three times its weight of water at  $60^{\circ}$ , and in its own weight at  $212^{\circ}$ . The *white vitriol* of the shops is a sulphate of zinc not crystallized. It is prepared on a large scale from sulphuret of zinc, calcined, moistened, and exposed to the action of the air; the zinc is oxidated, the sulphur is converted into sulphuric acid, and the materials, by lixiviation, afford the sulphate, which, by evaporation, is obtained in the state of a white granular mass, generally containing a little iron. Both salts consist of one atom of acid, 40, and one of oxide of zinc, 42, = 82; but the crystals contain 7 atoms of water, and the white vitriol only 3 atoms.

Nitric acid is decomposed by zinc with rapidity; by using a dilute acid, a solution is obtained, which, by evaporation and cooling, crystallizes in slender prisms, deliquescent, and readily soluble both in water and alcohol.

Muriatic acid likewise dissolves this metal, by enabling it to attract oxygen from the water, and combining with the oxide. The solution becomes gelatinous on evaporation, without affording crystals. It may be obtained, according to Dr Thomson, composed of exactly an atom of muriatic acid and one of oxide of zinc, being the only muriate, except muriate of ammonia, existing without water of



crystallization : when dry it is the chloride, which, urged by heat, is partly sublimed, partly decomposed. In chlorine gas, zinc inflames, especially when a gentle heat is applied ; the chloride of zinc thus produced is a soft solid, fusible and volatile, acrid and corrosive, soluble in water. It is also obtained by heating corrosive sublimate and zinc filings, and was known to the older chemists by the name of Butter of Zinc. Phosphoric acid dissolves zinc, by enabling it to decompose water so as to be oxidated ; and this solution does not crystallize, but rather becomes gelatinous on evaporation.

The salts of zinc are decomposed by the alkalis and earths. Its oxide is soluble in solutions of the fixed alkalis ; and hence, if in these decompositions an excess of alkali be added, the precipitate is redissolved. On this is founded a method of analyzing brass, which is an alloy of zinc and copper, the brass being dissolved in diluted nitric acid, the solution being decomposed by an alkali, and the precipitate, which consists of the oxides of zinc and copper, after being dried and weighed, being submitted to the action of solution of potash, by which the oxide of zinc is dissolved, while the oxide of copper remains undissolved. The fixed alkalis even act on metallic zinc, and promote its oxidation by water or atmospheric air.

This metal, having so strong an attraction to oxygen, decomposes the greater number of the metallic salts, precipitating the metal which is their base in its metallic form.

Zinc is supposed to be soluble in small proportion in hydrogen gas, forming what has been termed hydro-zincic gas ; it is obtained by passing the vapour of water over a red hot mixture of calamine and charcoal. With carbon, zinc does not combine in any considerable quantity ; but the zinc of commerce, during its solution in diluted sulphuric acid, deposits a black powder, which



consists chiefly of carbon with iron. Neither can zinc be easily united with sulphur, though the compound exists in nature, forming the ore named Blende; this sulphuret consists, according to Dr Thomson's analysis, of 67.19 of zinc, and 32.81 of sulphur, which are the proportions of one atom of sulphur, 16, to one of zinc, 33; but probably the zinc is rather underrated, and should be 34.

Zinc combines in general with the other metals. It impairs, even when added in very minute quantity, the ductility of gold and silver, rendering them also more hard. With copper, a series of alloys are formed, the most extensively used of any of the compound metals. The combination is not easily formed directly, owing to the volatility of the zinc; it is therefore usually effected by the process named cementation, copper-plates being stratified with calamine in powder mixed with charcoal, and exposed to the necessary heat; the zinc of the calamine is reduced by the charcoal abstracting the oxygen with which it is united; it unites with the copper; and this alloy being fusible, can be combined with additional proportions of copper or zinc. Brass is of these alloys, the one which contains the largest quantity of zinc, the proportion being one to three of copper; it has the advantage, from being more fusible than copper, of being more easily cast, and it is less liable to tarnish or rust. With a larger proportion of copper, the colour approaches more to red; pinchbeck and tombac are alloys of this kind. Zinc does not easily combine with iron, from the high temperature required to melt the iron; but when iron plates are immersed in melted zinc, the metals enter into combination at the surface.

It is principally in the formation of the alloys with copper that zinc is employed. Since the discovery of the practicability of extending it in thin sheets, it has also been



proposed to substitute it for some of the purposes to which lead is applied : but from the hardness and rigidity of the zinc, this has scarcely succeeded. Some of its preparations are employed in medicine.

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CHAP. XIV.—OF BISMUTH.

**BISMUTH** is a metal of a white colour, with a reddish tinge, liable to tarnish and become iridescent from exposure to the air ; its texture is foliated ; it is not very hard, is quite brittle, and has a specific gravity of 9.8. It is found native and mineralized by oxygen, and by sulphur ; the native bismuth is more abundant than the ores, and is merely freed by fusion from the earthy matter mixed with it.

This metal is very fusible, melting at  $470^{\circ}$  or  $480^{\circ}$ . It crystallizes very easily in cubes by slow cooling. When in fusion, if the air is admitted, its surface is soon covered with a greenish-grey powder, which is the oxide of bismuth ; it is also formed by exposing the metal to a stronger heat, when it burns with a weak flame, and forms a yellow powder. The oxide, by a powerful heat, is fusible into transparent glasses. The atomic weight of bismuth is inferred by Dr Thomson to be 72 ; and its oxide is therefore 80.

Bismuth is oxidated and dissolved by the acids ; its salts are in general decomposed by the affusion of water.

Sulphuric acid boiled on it dissolves it, sulphurous acid gas being disengaged. The salt consists of an atom of acid, 40, and one of base, 80, = 120. By the action of water this is resolved into a sub-sulphate and super-sulphate, the latter affording acicular crystals on evaporation.



Nitric acid is rapidly decomposed by bismuth ; the temperature rises, and dense red vapours are disengaged ; the metal is so highly oxidated that it retains little of the acid. With a diluted acid a more perfect solution is obtained, which by evaporation affords rhomboidal crystals. By the affusion of water a white precipitate is thrown down, the Magistery of Bismuth, as it has been named, which is probably a sub-nitrate. When the solution is decomposed by a solution of tartrate of potash, a very white precipitate is obtained, which forms the paint sometimes used for the complexion, known by the name of Pearl-white. It is liable to be blackened by sulphuretted hydrogen, and by the vapours of putrefying substances, in which this gas is present.

Muriatic acid combines with oxide of bismuth. The solution, when concentrated by evaporation, forms a thick soft mass, called Butter of Bismuth, which is a chloride, consisting of one atom of chlorine, 36, and one of bismuth, 72, = 108. The metal in filings inflames when projected into chlorine gas, and a similar compound is formed.

Bismuth combines with sulphur by fusion, forming a grey sulphuret having a metallic lustre. Sulphuretted hydrogen tarnishes the metal, and either pure or in the state of the hydro-sulphurets or sulphuretted hydro-sulphurets, throws down from solutions of its salts very dark-coloured precipitates ; by this action it forms with these solutions a subtile sympathetic ink.

Bismuth combines by fusion with the greater number of the metals, and in general communicates brittleness and fusibility. This property, with regard to fusibility, is well displayed in the formation of what is named the fusible metal, which consists of 8 parts of bismuth, 5 of lead, and 3 of tin : this melts at  $212^{\circ}$ , a degree of fusibi-



lity much greater than that of any of the metals of which it is composed : by some the proportions of one atom of lead, 104, one of tin, and two of bismuth, 144, are said to answer better ; but Mr Dalton has lately found, that the most fusible compound, which melts even at  $197^{\circ}$ , is formed by the union of one atom of lead, 104, one of tin, 58, and three of bismuth, 216, or about 3 parts by weight of tin, 5 of lead, and  $10\frac{1}{2}$  of bismuth. The addition of a little quicksilver renders it still more fusible, and a composition of this kind is used to coat the internal surface of glass globes. It adds too to the fusibility of tin, the alloy of equal parts melting at  $280^{\circ}$  : in a smaller proportion it increases the hardness of tin, and hence is used in the formation of pewter. An alloy of equal parts of tin, bismuth, and quicksilver, forms a compound of a flaky brilliant appearance, named Mosaic Silver, sometimes applied to ornamental purposes. It is principally in the formation of these alloys that bismuth is employed.

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CHAP. XV.—OF ANTIMONY.

THE native sulphuret of this metal is the substance to which the name antimony was originally applied ; but the name is now appropriated to the metal. To extract the metal, the native sulphuret, freed by fusion from the earthy matter mixed with it, Crude Antimony, as it is called, is fused with iron-filings, with the addition of a little nitre ; the sulphur combines partly with the iron, partly with the potash of the nitre ; and the metal is run out.

Antimony is of a light bluish-grey colour, with a lustre not much liable to tarnish ; its texture is very distinctly



plated ; its hardness is moderate ; it is quite brittle, so as to be easily beat to powder. Its specific gravity is 6.7.

At a heat a little above ignition, antimony melts, and in cooling it assumes a crystalline arrangement easily observed on the surface of the mass, and in its structure. At a full white heat it is volatilized.

Heated under exposure to the air, it is oxidated ; and if the heat be high, the oxide is volatilized, passing at the same time to a higher state of oxidation, and condensing in acicular crystals ; the oxidation, if rapid, is attended with a weak flame. By deflagration with nitre, it is also obtained at a high state of oxidation, the oxide remaining combined with a portion of the alkali of the nitre ; and it farther exists in various degrees of oxidation in its saline combinations. Proust supposed that there are only two oxides ; but the existence of three is now generally admitted, though chemists are not perfectly agreed as to their composition. Dr Thomson considers the equivalent of antimony to be 44, the protoxide to contain one equivalent of oxygen, 8, the deutoxide an equivalent and a half of oxygen, 12, and the peroxide two atoms of oxygen, 16. Berzelius regards the deutoxide and peroxide as acids rather than oxides,—the one he names *Acidum Stibiosum*, the other *Acidum Stibicum* : others have termed them *Antimonious* and *Antimonic* acids : as they exhibit none of the characteristic properties of acids, except that of uniting with a few bases, they may with more propriety be considered as oxides.

Antimony is acted on by the acids. Sulphuric acid boiled on it converts it into protoxide, and dissolves it, sulphurous acid being disengaged ; the sulphate of antimony, by evaporation, yields a mass which is very deliquescent, and is decomposed by water.

Nitric acid dissolves antimony, and muriatic acid acts



on it slowly; but the best solvent is the nitro-muriatic acid. Five parts of muriatic and one of nitric acid afford a perfect solution: this, by evaporation, is converted into the chloride, which is of a thick consistence, and melts on the application of a very moderate heat. From these properties, it was termed Butter of Antimony by the older chemists. It is commonly obtained by heating 1 part of antimony with  $2\frac{1}{2}$  of corrosive sublimate, when the chloride of antimony will distil over. It is formed also by burning antimony in chlorine gas: it consists of one atom of chlorine, 36, and one of antimony, 44, = 80. It is extremely corrosive: it liquefies by exposure to the air, from attracting a quantity of water sufficient to dissolve it: when water is poured upon it, it is decomposed, the water, acting by its quantity, abstracting a portion of the acid, and precipitating submuriate of antimony.

The other acids, though unable to dissolve antimony, combine with its oxides. Of these salts, the only one of any importance is the triple tartrate of antimony and potash. This has been long employed in medical practice, under the name of Emetic Tartar, as one of the mildest and most manageable of the antimonial preparations. Various processes have been followed for its preparation: that given in the Pharmacopœia of the Edinburgh College is to boil three parts of the crocus or brown oxide, obtained by deflagrating sulphuret of antimony with nitre, with four parts of bi-tartrate of potash, in thirty-two parts of water, for half an hour: the solution, when strained, is set aside to crystallize. In the London Pharmacopœia, what is termed Glass of antimony, and in the Dublin Pharmacopœia, an Oxide, or rather Submuriate of antimony, precipitated from a solution of the muriate prepared by digesting muriatic acid with a little nitric acid on sulphuret of antimony, is boiled with a similar proportion of bi-



tartrate of potash in distilled water. In all these processes, the excess of tartaric acid dissolves a portion of the protoxide, and the triple salt crystallizes. Mr Phillips recommends as a preferable process, to boil 100 parts of metallic antimony with 200 of sulphuric acid to dryness; 100 of the sub-sulphate thus obtained, boiled with an equal weight of bi-tartrate of potash, afford 90 parts of pure emetic tartar at the first crystallization. The tartrate of antimony and potash, according to Dr Thomson, is composed of one atom of potash, 48, two of tartaric acid, 132, and three of the protoxide, 156, with two of water, 18; its equivalent is therefore 354. The efficacy of tartar emetic, and the other preparations, appears to be owing solely to the protoxide of the metal, the peroxide having no medicinal power.

The alkalis appear to form combinations with the oxides of antimony: when the metal is deflagrated with twice its weight of nitre, the oxide, or acid as Berzelius regards it, remains in combination with the potash of the nitre.

Antimony combines with sulphur by fusion, and forms a compound similar in appearance to the native sulphuret, consisting of one atom of the metal, 44, and one of sulphur, 16, = 60. From the native sulphuret several preparations are obtained of importance from their medicinal use.

When native sulphuret or crude antimony is slowly roasted in a shallow vessel, greater part of its sulphur is dissipated, and the metal attracting oxygen becomes the protoxide, a portion of the sulphuret likewise remaining mixed with it. If this be exposed to an intense heat, it melts and forms a transparent glass of a dark brown or reddish colour, the Vitrified Oxide of Antimony, as it is named; it generally contains a little silex from its ac-



tion on the crucible, which probably promotes its vitrification.

The metal in the crude antimony is likewise oxidated by deflagrating it with nitre; the greater part of the sulphur is converted into sulphurous acid, which is partly dissipated, and partly combines with the potash of the nitre, and the protoxide of antimony is formed, which also retains combined with it a small quantity of sulphur which had escaped deflagration, *brown oxide*, or *crocus of antimony*, as it used to be named.

When sulphuret of antimony is fused with an alkali, with potash for example, and thrown into water, or when an alkaline solution is boiled upon it, part of it is dissolved. If the liquor is strained while hot, a red powder is deposited, which was named by the chemists Kermes Mineral. If an acid is added to the solution while warm and previous to this deposition, it combines with the alkali, and a precipitate of a reddish-yellow colour is formed, which used to be named Golden Sulphur of Antimony, but is now called Precipitated Sulphuret of Antimony. These two preparations are similar in their composition, being compounds of protoxide of antimony with sulphur and sulphuretted hydrogen, the antimony during the process being oxidated probably from the decomposition of the water by the alkaline sulphuret, the sulphuretted hydrogen being derived from the same source, and the oxide attracting this, with a portion of the sulphur, at the moment of precipitation. The kermes mineral is composed, according to Dr Thomson, of one atom of the protoxide, 52, and one of sulphuretted hydrogen, 17, = 69. The yellow precipitate appears to contain an additional proportion of sulphur or sulphuretted hydrogen.

The last preparation of this kind is one that has been celebrated as an empirical medicine, James's Powder, the



Phosphate of antimony and lime, as it has been named, for the process for the preparation of which we are indebted to Dr Pearson. It consists in exposing first to a moderate heat in an open vessel, and then to a stronger heat in a covered crucible for two hours, equal parts of the sulphuret of antimony, and shavings of hartshorn; or, according to the formula in the London Pharmacopœia, one part of the sulphuret to two of horn. This sulphur is dissipated, the metal is oxidated, the animal matter of the bones is burned out, and the phosphate of lime, which is the solid matter of the bones, remains intimately mixed, or perhaps combined with the antimonial oxide. According to Dr Pearson's analysis of it, it consists of 43 parts of phosphate of lime, and 57 of an oxide of antimony. Mr Phillips has shown that these numbers are nearly correct; but instead of finding, like Dr Pearson, a considerable proportion of protoxide in the powder, it contains 56 parts of the inert peroxide, and not more than 1 part of protoxide. The Pulvis antimonialis of the Pharmacopœia, he found to consist of 36 of the peroxide, and 63 of phosphate of lime.

Antimony forms with phosphorus a white compound with metallic lustre, which burns with a green flame when thrown upon ignited fuel.

Antimony combines with nearly all the metals. Its alloys are in general brittle, and few of them have been applied to any use. With tin it forms a ductile alloy, and in which the metals so far modify each other, that the usual effects of re-agents on them are not obtained. Fused with lead, it affords an alloy, of which printing types are cast; according to Mr Dalton, large types consist of 13 antimony, and 87 lead, middle-sized types of 18 and 82, and small types 30 and 70: these alloys are tolerably hard, without being brittle, and thus take a delicate im-



pression from a mould, owing probably to the expansion which antimony suffers in consolidating from fusion.

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CHAP. XVI.—OF ARSENIC.

THE term Arsenic is in common language applied to the oxide of the metal which, in chemical nomenclature, is called by this name; this oxide, obtained by sublimation from certain metallic ores, particularly those of cobalt, having been known before the metal itself. To obtain the metal, the oxide is mixed with twice its weight of black flux, and the mixture exposed in a crucible, to which another is adapted, to a heat gradually raised to ignition; the oxygen of the oxide is abstracted by the carbonaceous matter, and the metallic arsenic is sublimed.

This metal is of a bluish-grey colour, with considerable lustre, which, however, is soon tarnished from exposure to the air; it is extremely brittle, so as to be easily reduced to powder: its specific gravity is 8.31. It is so volatile that its fusion cannot easily be accomplished. It passes into vapour when heated to about 388° of Fahrenheit. When condensed slowly, it forms octohedral crystals. In the state of vapour it has a strong and peculiar smell, very similar to that of garlic.

In volatilizing, if the atmospheric air is admitted, it is oxidated rapidly, a white vapour being produced, which is the white oxide; if the heat is raised somewhat higher, the metal burns with a dull blue flame, and the production of the same oxide. Its properties are peculiar; it is fusible and volatile; it is not, like the greater number of metallic oxides, insipid, and insoluble in water; its taste



is sharp and acrid, and it is soluble in cold, and still more in hot water; the latter solution affording, on cooling, tetrahedral crystals. Its solubility has been variously estimated: the results most to be depended on are those of Klaproth. He found 1000 parts of boiling water to dissolve 78 parts, and to retain in solution after cooling 30 parts, while without heat this quantity of water dissolves only  $2\frac{1}{2}$  parts. This oxide combines with the alkalis, and it even reddens, it is said, the infusion of litmus, an effect I have not, however, been able to observe. Hence it has been regarded rather as an acid than an oxide, and has received the name of Arsenious Acid. Yet it is on the whole more analogous to oxides in a high state of oxidation; for it is incapable of neutralizing the alkaline properties, while it forms salts with the acids. It consists, according to Thomson, of an atom of arsenic, 38, and two of oxygen, 16, = 54: it is thus a Deutoxide of Arsenic. It is this substance which is the most virulent of the metallic poisons. Sulphuret of potash has been recommended as an antidote, but does not appear to be an effectual one. Lime water is said to be of more utility, the earth forming an insoluble inert compound with the white oxide.

Arsenic is capable of acquiring acid powers by a higher degree of oxygenation. This is effected by distilling nitrous acid from the white oxide, the acid yielding an additional atom of oxygen; or with more facility, by dissolving the oxide in muriatic acid, with the assistance of heat, adding to this nitric acid, and distilling until the production of nitrous vapours ceases. By raising the heat at the end of the process to redness, the arsenic acid is obtained in the solid form. It consists of an atom of arsenic, 38, and three of oxygen, 24, = 62.

The OXIDE of arsenic combines with the different acids; the same compounds are produced by the action of the



acids on metallic arsenic, the acid first yielding oxygen, and then combining with the oxide. Sulphuric acid dissolves the oxide when boiled on it, forming a compound which, as the solution cools, is deposited in crystalline grains. Nitric acid, when much diluted, also dissolves the oxide. Muriatic acid, digested on metallic arsenic, causes its oxidation by the decomposition of water; the hydrogen disengaged has a very fetid odour, from a portion of oxide which it holds dissolved. The acid boiled on oxide of arsenic dissolves one-third of its weight nearly, forming a chloride. The chloride of arsenic is obtained also by distillation from a mixture of corrosive sublimate and metallic arsenic; the product is partly liquid, partly congealed; and from its consistence was named Butter of Arsenic. It emits acrid vapours, is deliquescent; by the affusion of water, it is decomposed. The other acids scarcely act on the metal, but combine with its oxide, forming compounds of sparing solubility.

Oxide of arsenic combines with the alkalis. The combinations with the fixed alkalis are formed by fusion; and even the solution of the alkali, boiled on the oxide, dissolves a large portion of it; the solution, when concentrated, being viscid, of a brown colour, and unpleasant odour. Ammonia likewise dissolves a quantity of the oxide; and it combines in the dry way, by the application of heat, with lime and some of the other earths.

ARSENIC ACID has all the most important acid properties. It is abundantly soluble in water, requiring only six parts for its solution at  $60^{\circ}$ , and not more than two parts at  $212^{\circ}$ ; its taste is sour; it reddens the vegetable colours, and combines with salifiable bases, forming in the due proportion neutral compounds.

Arsenic acid combines with the alkalis, forming salts soluble and crystallizable. They may be obtained by di-



rect combination, and also by an indirect method, that of heating the white oxide with any of the alkaline nitrates; the nitric acid is decomposed, yielding oxygen to the oxide, so as to convert it into arsenic acid, with which the alkaline base of the nitrate combines. The arseniate, or rather binarseniate of potash, crystallizes in large tetrahedral prisms: the regularity of its crystallization is owing to its excess of acid. The arseniate of soda crystallizes in hexahedral prisms; arseniate of ammonia in rhomboidal prisms.

Arsenic acid combines with the earths, forming compounds of very sparing solubility, but which are rendered more soluble by an excess of acid. It acts also on several of the metals, yielding oxygen to the metal, and being thus reduced to the state of the oxide. When the metal is previously oxidated, the arsenic acid enters into union with the oxide; but these combinations present no important results.

Metallic arsenic is dissolved by hydrogen gas. This compound is formed when zinc is acted on by arsenic acid, or from the mutual action of diluted sulphuric acid, zinc, and oxide of arsenic, or from the action of muriatic acid on an alloy of arsenic and tin. It has the peculiar odour which arsenic has when in the state of vapour, and its effects are very deleterious; it is much heavier than pure hydrogen gas, its specific gravity being 0.5293. When detonated with atmospheric air, it deposits a film of metallic arsenic; when detonated with oxygen gas, oxide of arsenic is deposited. It is decomposed by nitric oxide gas, arsenic, or its oxide being formed, according to the proportions in which the gases are mixed: chlorine gas precipitates metallic arsenic from it. There appears also to be a solid compound of arsenic and hydrogen, which is formed when arsenic is employed as the negative



wire in decomposing water by galvanic action; it falls down in the state of a brown powder, and the evolution of gaseous hydrogen is less copious.

Arsenic unites with sulphur by fusion or by sublimation, forming two compounds, which also occur native. The proto-sulphuret, of a red colour, named Realgar, consists of one equivalent of arsenic, 38, and one of sulphur, 16, = 54. The sesqui-sulphuret, of a yellow colour, called Orpiment, consists of one equivalent of arsenic, 38, and one and a half of sulphur, 24, = 62.

Arsenic combines with nearly all the metals; the ductile metals it renders brittle, and to those that are refractory in the fire it communicates fusibility. That with copper is of a white colour, and receives a fine polish; and hence has been used instead of pure copper in forming silver-plating; but it has the disadvantage of tarnishing on exposure to the air. Oxide of arsenic exerts affinities to other metallic oxides, and hence decomposes some of the metallic salts. The precipitate which its solution in potash throws down from a solution of sulphate of copper, named Scheele's Green, is a combination of this nature; it is of a bright green colour, and is used as a pigment.

A part of the chemical history of Arsenic is that relating to the tests by which it is detected, as, from being so active a poison, this is occasionally the subject of judicial investigation. If any white powder has been procured by washing the stomach after death, it may be subjected to the following tests: The most decisive is, that of reducing a little of the oxide; this is done by exposing it mixed with twice or thrice its weight of the black flux, in a coated glass tube lightly stopped, to a low red heat cautiously raised: a metallic crust of a grey colour and great brilliancy is obtained on the sides of the tube. The only disadvantage of the test as commonly performed is, that



it requires a quantity of several grains. Dr Traill has shown, however, that by skilful manipulation a much smaller quantity of the white oxide may be detected with certainty. His method is to mix the suspected powder with the black flux, and simply to heat it in a small glass tube by a spirit lamp: if arsenic is present, it will in less than two minutes be reduced and volatilized, and will form a shining crust on the upper side of the inclined tube. In this manner he has obtained a distinct metallic crust from so minute a quantity as one-tenth of a grain of the white oxide. 2d, A little of this reduced metal, when put on a red-hot iron, is volatilized, and the vapour, in exhaling, has a peculiar odour, approaching to that of garlic. The oxide is also volatilized by the same degree of heat, forming a white smoke; and if it has been previously mixed with a minute quantity of oil, it will, in evaporating, give the garlic odour; this odour, it is to be remarked, however, is not very evident where a small quantity is employed, and it is disguised by the intermixture of vegetable and animal substances. 3d, If a little of the reduced metal, or a small quantity of the oxide made into a paste with charcoal and oil, be placed between two copper plates, and if these are bound together by wire, and exposed to a red heat in a charcoal fire for a quarter of an hour, the surface of the copper will be permanently whitened, so that, on rubbing it with a little chalk, it will have a silvery appearance from the alloy of the copper and arsenic. This and the former test may give greater certainty to an opinion formed from other results, but cannot of themselves be relied on as unequivocal. 4th, If a little of the oxide be dissolved in warm water, with three times its weight of carbonate of potash, the solution, on being added to a solution of sulphate of copper, throws down a precipitate of a lively grass-green colour, Scheele's



green, as it is termed. This and the following tests may also be applied to the fluids taken from the stomach after sudden death, when arsenic is suspected to exist in them; but the results are much less satisfactory than when a powder has been procured, and precautions against deception are necessary. The test with sulphate of copper is one extremely delicate, and when applied to a solution of the oxide of arsenic in water is unequivocal, but when applied to mixed fluids from the stomach is liable to fallacy. It has been affirmed, that a strong decoction of onions will, on the addition of the alkali, and afterwards of the sulphate of copper, give a green precipitate, exactly resembling that from arsenic; but this has been shown by Dr Paris to be a mistake, arising from the alkali changing the colour of the vegetable extract to yellowish brown, when the blue precipitate seen through it will appear green. To avoid this deception, Dr Paris recommends, that the suspected liquor, and the solutions of copper and alkali, should be mixed on a sheet of white paper. According to Dr Christison this test will not throw down oxide of arsenic from some mixed liquors, as tea and porter, it is supposed from the oxide having affinities to several vegetable principles. When a precipitation of Scheele's green does happen, precautions being used against deception from the colour of the fluid, it appears to be one of the most certain indications of arsenic. To render it more evident by contrast, a little of a solution of carbonate of potash alone ought to be added to another quantity of the same solution of sulphate of copper; the precipitate it forms is of a bluish-green, and the difference is sufficiently evident when they are compared in the light of day.

5th, A very delicate test proposed by Mr Hume, is that of nitrate of silver: If a piece of the common fused nitrate,



or lunar caustic, be applied to the surface of a solution of so small a quantity of white oxide of arsenic as one grain, with an equal weight of carbonate of soda, in ten or twelve ounces of boiling distilled water, a bright yellow precipitate instantly falls down. Dr Marcet employed a similar test: To the surface of any fluid containing oxide of arsenic in solution, let a glass rod, dipped in a solution of ammonia, be applied; and let another rod, dipped in a solution of nitrate of silver, be brought into contact with the mixture. A precipitate of a lively yellow colour, inclining to orange, falls down. An excess of ammonia ought to be avoided, as it renders the precipitate soluble, and on this account the other mode with carbonate of soda is less liable to fail. The presence of an alkali is essential in applying the tests both of nitrate of silver and sulphate of copper, for the oxide of arsenic alone is not able to attract the oxide of silver or of copper from the powerful acids with which it is combined, unless with the aid of the affinity of an alkali to these acids. This test of nitrate of silver appears to be one both delicate and certain, and considerable reliance is hence usually placed upon it. The chief objections which have been made to it are the following. First, that the soluble salts of phosphoric acid also give a yellowish precipitate with it. This source of error can be obviated by the way of performing the experiment, as in the manner proposed by Dr Paris, of making a broad line with the suspected liquor on white paper, and then drawing a stick of lunar caustic along it; if the yellow precipitate is produced by phosphoric acid it will be homogeneous and smooth, as if laid on with a brush, while, if it is from oxide of arsenic, it will be curdy and flocculent: a still more distinctive character is, than in less than two minutes the phosphorical yellow fades into a dark green, while that from arsenic continues for some time unchanged, and then



becomes brown; or the method of Mr Phillips may be used, of mixing the coloured fluid with animal charcoal, and allowing it to stand for a short time, a method which, with the precautions he has pointed out, may be employed with much advantage. The risk of a precipitate from phosphoric acid is in a great measure avoided by an elegant modification, which Mr Hume has lately made of his original test; it is that of employing an ammoniacal nitrate of silver. This is made by dropping liquid ammonia into a solution of nitrate of silver until the oxide is precipitated, and continuing to add the ammonia cautiously until the precipitate is nearly redissolved. When the liquor thus prepared is added to a fluid containing white oxide of arsenic, the yellow precipitate is immediately formed, the ammonia remaining in union with the nitric acid; and this test can have little or no effect on phosphoric acid, for phosphate of silver is soluble in ammonia. Another advantage of it is, that the ammonia is in the precise proportion for saturating the nitric acid, so that there can be no excess of alkali to redissolve the arsenical precipitate. The second objection to the use of nitrate of silver is, that soluble muriates produce with it precipitates so copious and so modified in their appearance, as to be very liable to produce errors. The best way of remedying this is to add the test till every substance is thrown down which it can precipitate, and then to expose the mixed product to heat, by which oxide of arsenic will be sublimed. Lastly, it has been proved by Dr Christison, that the compound of oxide of arsenic and oxide of silver is retained in solution by several vegetable infusions, as by the tannin in tea, by the tartaric acid in wine, &c. In such liquids, the best method is to apply the next test. 6th, That of Sulphuretted hydrogen gas, which produces from any solution of white oxide of arsenic a



yellow precipitate of sulphuret of arsenic or orpiment. This is a test equally delicate and accurate; it only requires the addition of acetic acid to saturate any alkali that may be present; the precipitate thrown down is not unequivocal, as other metals may produce it; but by the application of heat, in the manner stated with regard to the white oxide itself, the metal may be reduced, and its presence established. This application of sulphuretted hydrogen has been recommended by Dr Christison as the most certain of all the tests of arsenic. It is not, however, proper to rely upon any of the tests which have been mentioned, singly, especially of those applied to the liquids taken from the stomach, but to obtain the concurring evidence of several, which will then be decisive.

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#### CHAP. XVII.—OF CADMIUM.

CADMIUM is a metal bearing considerable resemblance to arsenic, which was discovered by Stromeyer in 1817. He detected it in a preparation of zinc from Silesia, which had been supposed to contain arsenic, and afterwards in a variety of blende. It has been since found by Dr Clarke, in the zinc ores of Derbyshire, and by Mr Herapath in a sublimate which rises in the process for obtaining zinc by distillation. To obtain the cadmium unmixed with the oxide of zinc, the following process is followed: The ore, or the zinc of commerce, is dissolved in sulphuric acid, an excess of acid is added, and sulphuretted hydrogen gas is then made to pass through the solution, till the whole of the cadmium is precipitated, along with any portions of zinc or copper that may be present. The precipitate is redissolved in muriatic acid,



and carbonate of ammonia added; the carbonate of cadmium falls down unmixed, and by heating it to redness, the oxide of cadmium is obtained pure. The metal may be obtained by exposing the oxide to heat with carbonaceous matter.

Cadmium is of a white colour, with considerable lustre, bearing much resemblance to tin: it is soft and malleable, and has a specific gravity above 8.5. It melts below a red heat, and is converted into vapour at a temperature little above the boiling point of mercury; it crystallizes in regular octohedrons. It is little altered by exposure to the atmosphere; when heated in contact with the air it burns like zinc, with the production of a brownish-yellow oxide. Its equivalent is inferred to be 56, and that of its oxide 64. The acids oxidate cadmium, and combine with its oxide. The Sulphate of cadmium crystallizes in prisms, which are efflorescent and very soluble in water. Nitrate of cadmium crystallizes in deliquescent acicular prisms. Muriate of cadmium crystallizes in small rectangular prisms. These lose their water of crystallization when heated, becoming chloride of cadmium; by a much stronger heat they are sublimed. Iodide of cadmium crystallizes in large six-sided tables, having a pearly lustre. By a strong heat the iodine is driven off.

The Salts of cadmium are decomposed by the alkalis, and the oxide is precipitated in the state of a white hydrate. Ammonia, when added in excess, redissolves the precipitate it throws down. Prussiate of potash throws down a white precipitate from solutions of cadmium. Sulphuretted hydrogen and the hydro-sulphurets occasion a yellow precipitate, which is sulphuret of cadmium. It resembles orpiment, but may be easily distinguished by its dissolving with facility in muriatic acid, and by bearing a



red heat without being altered. It is obtained also by heating sulphur with oxide of cadmium: its yellow colour changes on exposure to heat, first to a brown, and then to a carmine red; but on cooling it resumes its original colour. By an intense heat it is melted, and crystallizes on cooling in transparent yellow plates. Cadmium forms alloys with various metals, none of which are of any importance.

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#### CHAP. XVIII.—OF COBALT.

THIS metal occurs in nature alloyed with arsenic, nickel, and other metals, and mineralized by oxygen, and by arsenic acid; it exists also in meteoric stones. It is obtained after the ore has been roasted and calcined, in the state of an oxide impure from the presence of other metallic oxides. This, with an intermixture of siliceous earth, forms the Zaffre of commerce. When this oxide is mixed with thrice its weight of black flux, a little sea-salt and oil, and urged with an intense heat, it is reduced, and affords metallic cobalt, alloyed, however, with portions of arsenic, nickel, and generally of iron. To free it from these, the least difficult process is to again oxidate the reduced metal by deflagration with nitre, which converts the iron into peroxide, and the arsenic into arsenic acid; the latter combines with the potash, and by washing with water is removed; the residue is then digested in nitric acid, which dissolves the oxide of cobalt, but not the peroxide of iron: potash is then added, by which the oxide of cobalt is precipitated, and it may then be reduced to the metallic form. Instead of nitric acid, oxalic acid may be



used, and the oxalate of cobalt afterwards be decomposed by heat.

When cobalt is obtained in a state of purity, it is of a white colour, inclining to grey, and, if tarnished, to red, with moderate lustre; its fracture is compact; it is hard and brittle; its specific gravity is 7.8. Like nickel, it is sensibly magnetic; and this nearly as powerfully as iron, and when it has been purified, so that no traces of that metal are discoverable by the most delicate tests.

Cobalt requires a very intense heat to melt it: its fusing point has been estimated at  $130^{\circ}$  of Wedgwood's scale. At a temperature much inferior to this, it suffers oxidation from the action of the air: this, which is the protoxide, is of a deep blue colour; a precipitate of a lighter colour, probably a hydrate, is thrown down from its saline compounds by the alkalis. When exposed to the air in a humid state, the protoxide absorbs oxygen; it assumes an olive colour, and when heated in contact with the air, it becomes brown, and at length nearly black. There is much uncertainty respecting the nature of these two oxides. Dr Thomson infers the atomic weight of cobalt to be 26, that the protoxide contains one atom of oxygen, whence its equivalent is 34, and the peroxide one and a half, which will make its equivalent 38.

The acids combine with protoxide of cobalt. When sulphuric acid is boiled on cobalt, sulphurous acid is disengaged, and a saline matter is obtained of a reddish colour, which is sulphate of cobalt. This, when dissolved, affords, by evaporation, acicular crystals, of a reddish tinge. Nitric acid oxidates and dissolves the metal in the cold: the solution is of a red colour, and affords on evaporation minute prismatic crystals, which are deliquescent. Muriatic acid, to act on cobalt, requires the application of heat; it dissolves the oxide more readily, forming a



solution of a reddish tinge, and which by evaporation affords needle-like crystals of the same colour. The metal inflames when heated in chlorine gas. Phosphate of cobalt may be obtained by mixing solutions of muriate of cobalt and phosphate of soda; it is precipitated of a lilac colour: according to Thenard, if this be mixed with 8 parts of fresh precipitated alumina, and dried, a blue pigment will be formed, resembling ultramarine.

The solutions of the salts of cobalt afford a sympathetic ink, lines traced with them on paper being invisible when cold, but becoming blue or green when heated, the green colour disappearing again as the paper cools. The solution usually employed for this purpose is prepared by dissolving one part of zaffre in two of diluted nitric acid, with the aid of heat, adding to it of muriate of soda one part, and diluting with twenty parts of water. A red sympathetic ink is formed by dissolving pure oxide of cobalt in acetic acid; and a purple one by dissolving it in distilled vinegar, and adding to the solution muriate of soda. The cause of these changes of colour has been supposed to be the dissipation of humidity from the salt; but I have found them to take place in the solution itself; and they probably depend merely on the elevation of temperature, which, as Gay-Lussac has shewn, alters the colours of metallic oxides as well as of many other substances.

The salts of cobalt are decomposed by the alkalis and earths, precipitates being thrown down of a red tinge; or, according to Thenard, if the cobalt is pure, of a blue colour. By an excess of alkali, they are redissolved, particularly when ammonia is employed. Oxide of cobalt vitrifies with siliceous earth, forming a deep blue glass, the Smalt of commerce.

Sulphuret of cobalt and the alloys of cobalt have been little examined, and are applied to no use.



Cobalt is principally employed to give a blue colour to glass, a portion of its oxide being fused with the glass. Its oxide is applied by the proper flux to give the blue colour in painting on porcelain; and vitrified with siliceous earth it forms Smalt, which is used to give a blue tinge to paper and to linen.

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## CHAP. XIX.—OF NICKEL.

THIS metal is usually obtained from an ore, the kupfer-nickel of mineralogists, in which it exists combined with arsenic, and a small portion of sulphur. It is extracted by calcining the ore, mixing the residual substance with twice its weight of black flux, and applying the intense heat of a forge; a metallic button is obtained, composed of the nickel alloyed with small portions of other metals. These it is difficult to abstract entirely, and complicated processes are required to obtain nickel perfectly pure. The solubility of its oxide in ammonia, and its being precipitated from this solution by potash, affords the most perfect mode of separating it from iron and cobalt, the metals with which it is most usually contaminated, as their oxides are either not dissolved by the ammonia, or not precipitated by the potash.

When obtained in a state of purity, it is of a white colour, intermediate between that of silver and tin, with considerable lustre; it is hard, but has considerable ductility and malleability, so that it can be forged into thin plates; its specific gravity is 8.6. It is sensibly magnetic, a property which had been supposed to depend on the presence of iron. But it belongs to nickel itself; for instead of be-



coming weaker as the metal is purified, it becomes stronger, and at length is nearly equal to the same property in iron. The effect of the magnet on pure nickel is little inferior to that on iron; it can also be rendered magnetic, and magnetic needles have been constructed of it, which have the advantage of not being liable to rust.

Nickel is extremely infusible; it is imperfectly agglutinated even in the heat which melts malleable iron. When heated under exposure to atmospheric air, it is oxidated, though with difficulty; by submitting it to heat mixed with nitre, its oxidation is effected with more facility. Its oxide in the state of a hydrate is thrown down of an apple-green colour, by precipitation from some of its saline combinations. This is the protoxide; when it is exposed to a continued red heat, or to the action of chlorine gas, it passes to the state of peroxide, and becomes of a black colour. Chemists are not agreed about the composition of these oxides. Dr Thomson conceives that the equivalent of nickel is 26, that its protoxide consists of one atom of nickel, 26, and one of oxygen, 8, = ~~34~~<sup>34</sup>; and the ~~34~~<sup>34</sup> peroxide appears to contain two atoms of oxygen. Lassaigne, again, estimates the equivalent of oxygen at 40, Phillips at 29, Brande at 30; differences which can be resolved only by farther investigation.

Nickel is oxidated and dissolved by the acids; its salts are usually of a green colour. Sulphuric acid requires the aid of heat; and by evaporation of the solution, crystals of a pale green colour are obtained. Nitric acid forms a solution of a rich green colour, and rhomboidal crystals of the same colour are formed on evaporation. Muriatic acid acts more weakly on the metal, but dissolves its oxide, and likewise forms crystals of the same colour. When it is heated in chlorine gas, it affords a product of an olive colour. The carbonate formed by double affinity is of an apple-green colour.



The salts of nickel are decomposed by the alkalis and earths, and precipitates of a green colour thrown down. When the alkali is in excess, the precipitate is redissolved. The pure oxide is likewise soluble in the alkaline solutions; the solution in liquid ammonia is of a rich blue colour, similar to that of copper in the same alkali; but what has been pointed out as characteristic of nickel, is, that the colour gradually changes to purple, and lastly to violet; the violet, by the addition of an acid, is changed to green; but on adding ammonia, the blue colour is restored. An effect rather singular, is the precipitation of the oxide of nickel from liquid ammonia by potash or soda.

Nickel combines with sulphur by fusion, forming a sulphuret of a grey colour, hard and brittle; and also a bisulphuret, in which the magnetic property is lost. With the metals it forms alloys. In the alloy with gold and with platina the magnetic power remains; in that with copper it is lost. With iron it forms an alloy of a silvery white colour, and it is singular that meteoric iron always has an alloy of nickel: its quantity in this varies from 2 to 17 *per cent.* The white copper of the Chinese consists, according to Dr Fyfe, of 40.4 parts of copper, 25.4 of zinc, 31.6 of nickel, and 2.6 of iron. Its oxide combines by fusion with the vitrifiable earths, and forms glasses of a hyacinthine colour.

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CHAP. XX.—OF MANGANESE.

**M**ANGANESE occurs in nature combined with oxygen, and in this state had been used in some arts, particularly in the manufacture of glass, to render it free from colour, before its nature was known. Scheele and Bergman, from



an examination of this mineral, inferred that it is the oxide of a peculiar metal, and this metal has since been procured in its pure form. The native oxide of manganese has generally an intermixture of iron, copper, and lead, and it is difficult to free it from these. Mr Faraday has found, that if it be heated with muriate of ammonia, the chlorine will combine with the manganese in preference to any of the other metals; so that if an excess of the oxide be used, the chloride of manganese formed will be perfectly pure: by dissolving it in water, and adding solution of carbonate of potash, carbonate of manganese will be precipitated, from which the acid may be expelled by heat. It may be procured pure also by a process given by Mr Hatchet, that of dissolving the black oxide in muriatic acid, and adding ammonia to the solution largely diluted; the oxide of iron which is precipitated is separated by a filter; the oxide of manganese is obtained pure by evaporating the solution to dryness, and expelling the muriate of ammonia by heat.

To obtain metallic manganese, the pure oxide reduced to powder is made into a paste, with a small quantity of oil and charcoal, and exposed in a crucible to the most intense heat which the most powerful wind furnace can raise; in this way, it may be reduced to the metallic form. This reduction is difficult, from the tendency of the oxide to run into a glass when any flux is mixed with it, or even from contact with the earth of the crucible; hence the necessity of imbedding it in charcoal powder, and of lining the crucible with a paste of charcoal. Mr Faraday obtained the metal, by strongly heating the tartrate of manganese alone. Hydrogen gas passed over the heated oxide will also reduce it. The metal, from its great infusibility, is not easily procured in any other state than that of globules. It is of a white colour, with a shade of grey, with moderate lustre, which tarnishes, however, on



exposure to the air; its texture is granular; it is brittle and hard; its specific gravity is 8.

When metallic manganese is exposed to heat in contact with the air, it passes rapidly through different stages of oxidation, becoming grey, yellow, red, brown, and at length black; this black oxide being the metal at the *maximum* of oxidation, and the same with the native oxide. The existence of at least three distinct oxides of manganese seems to be fully established. The protoxide is that which exists in the salts of manganese. It may be obtained by passing a current of hydrogen gas over ignited carbonate of manganese, or simply over the deutoxide heated in a glass tube, or by exposing the carbonate, or any pure oxide of manganese, to a strong heat in a charcoal crucible. It is of a rich green colour, but becomes brown on exposure to the air, from passing to the state of deutoxide. So strong is its attraction to oxygen, that when heated to above  $600^{\circ}$  in an open vessel, it even takes fire, burning slowly with a reddish light. It appears, from the experiments of Thomson and Berzelius, to consist of one atom of metallic manganese, 28, and one of oxygen, 8; hence its equivalent is 36. It is thrown down from the salts of manganese by alkalis in the state of a white hydrate.

The deutoxide, or brown oxide of manganese, may be formed by exposing the green protoxide for some time to the air, but is usually obtained by exposing the black peroxide to a low red heat, as in the usual process for procuring oxygen gas: it is of a dark brown colour. According to Arfwedson and Dr Thomson, the same oxide, but of a shining black colour, is obtained by exposing the nitrate of manganese to a red heat in a platina crucible. To form a regular series, it should contain two equivalents of oxygen; but it appears to contain only one and



a half; or it consists of manganese, 28, and oxygen, 12, = 40. It absorbs oxygen on exposure to the air, and passes to the state of peroxide. It is soluble in some of the acids in the cold, particularly in the sulphuric and muriatic, forming very deep red solutions: these are not permanent: if the temperature be at all raised, the deutoxide is resolved into the protoxide, which remains in solution, and the peroxide, which is precipitated. The same effect happens when the deutoxide is digested in concentrated nitric acid. The grey ore of manganese appears to be a hydrate of the deutoxide.

The tritoxide, or peroxide of manganese, is the common black oxide of commerce. It may be formed artificially by heating the nitrate of manganese to a certain point, so that all the acid, but none of the oxide, shall be decomposed. It is found to be composed of one atom of manganese, 28, and two of oxygen, 16, = 44. It appears to be too highly oxidated to combine with the acids; hence it is not dissolved by them, unless it is deprived, by some de-oxidating agency, of part of its oxygen. It is insoluble in water: when exposed to a red heat, it is converted into the brown deutoxide; but by no heat, however intense, can it be reduced to the metallic form, or even to the state of protoxide,—a fact exemplifying, in a striking manner, the principle developed by Berthollet, that quantity of matter has a powerful influence on affinity.

Besides these three oxides, of which the constitution is established with considerable certainty, some others have been inferred by different chemists to exist. In particular, a green oxide was obtained by Dr John, by the action of metallic manganese on water, which appeared to contain half the quantity of oxygen that exists in the protoxide, or to consist of one equivalent of manganese, 28, and half an equivalent of oxygen, 4, = 32: If its exis-



tence is proved, it may be termed a sub-oxide. Another oxide of a red colour, intermediate between the protoxide and deutoxide, is obtained by exposing the latter to a white heat. It is regarded by Berzelius as merely a mixture of these two oxides; by Berthier as a compound of them in the proportions of one atom of protoxide and two of peroxide \*.

The salts of manganese are usually prepared from the black peroxide. The acids which have a strong affinity to the protoxide, expel the excess of oxygen, especially if their action is aided by heat; with other acids it is necessary to add a little carbonaceous matter, as sugar, to abstract a portion of oxygen from the peroxide. The chief salt is the sulphate of manganese, which may be thus prepared. The acid acts very slowly on the metal itself; if diluted, however, it acts more quickly, hydrogen gas being disengaged of a fetid smell. The solution when concentrated is of a rose colour; when obtained neutral, it affords on evaporation granular crystals of a reddish

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\* It has become customary, when the composition of an intermediate compound does not agree with the doctrine of atoms, to regard it as either a mixture or a combination of a higher and a lower compound; and accordingly, I have usually stated this explanation in the text. At the same time it does not appear to be a satisfactory one. When, as in this red oxide, the colour is distinct and constant, it is certainly an improbable supposition, that it is a mere mixture of other bodies of different colours; we cannot conceive how a brown substance, mixed with a green, should produce a uniform red. The other opinion, that a body in one state of oxidation can combine with itself in another state, is, as my Father remarked, little better than a verbal distinction; or, at least, it is an hypothetical assumption, by which the fact is accommodated to the theory. ED.



colour, and by slow evaporation large crystals of a rhomboidal form, of a light rose colour, transparent and soluble.

Nitric acid does not dissolve the black oxide of manganese; but if any substance is added which attracts oxygen from the acid, this enables it to act on the oxide, and reduce its state of oxidation, and then the solution is effected. A little alcohol or sugar has this effect, or, as Scheele shewed, exposing the acid with the oxide to the solar rays. The solution is colourless, and when decomposed by the alkalis, gives, if free from iron, a white precipitate.

Muriatic acid is equally incapable of combining directly with the black oxide, but, according to the usual law, it de-oxidates it. On the present theory, one part of the muriatic acid is decomposed; its hydrogen combines with the excess of oxygen of the black oxide to form water; the chlorine, the other element of this portion of the acid, is evolved, and the rest of the muriatic acid unites with the protoxide of manganese. On the old doctrine, part of the muriatic acid combined with the protoxide, while the rest, uniting with the excess of oxygen present, became oxymuriatic acid. It was from this process of procuring oxymuriatic acid that the latter theory originated; the excess of oxygen in the black oxide disappeared along with a portion of muriatic acid, and this green gas, being the only apparent product, was hence inferred to be a compound of these. The solution of muriate of manganese is of a rose colour when concentrated, and affords by evaporation small crystals of a pale rose colour, or, by slow evaporation, large and regular transparent crystals, which are four-sided tables: they are deliquescent, and very soluble in water. By a red heat they are converted into a red chloride. Carbonate and Phosphate of manganese may be formed by double decomposition, being thrown down



in the state of insoluble precipitates. The salts of manganese suffer decomposition from the alkalis which precipitate the oxide. They are not decomposed by the inflammables or the other metals, a proof of the strength of affinity of manganese to oxygen.

It is generally believed, that black peroxide of manganese is capable of uniting with additional proportions of oxygen, and of acquiring from these acid properties. The process in which these new acids, *manganeseous* and *manganesic*, as they are termed, are supposed to be formed, consists in submitting the peroxide to the action of the fixed alkalis. The peroxide is mixed with an equal weight of nitre or of carbonate of potash, or with five or six parts of solid caustic potash, and the mixture exposed to a red heat. A green coloured mass is procured, which, when thrown into water, is dissolved, exhibiting rapid changes of colour during its solution; the liquor is first green, then changes to purple, violet, and red, a brown sediment then falls, and the fluid becomes colourless; from these singular phenomena, the solid compound was termed the *mineral chameleon*. It was supposed that these variations of colour arose from rapid changes of oxidation; but a different view has been given by Messrs Chevillot and Edwards. They made the important observation, that during the fusion of the peroxide with the alkali, the mixture absorbs oxygen; hence they inferred, that an acid was produced, the manganesic, which, uniting with different proportions of potash, occasioned different colours. By rapid evaporation of the red solution, they obtained small prismatic crystals of a purple colour, which they considered to be manganesiate of potash. This substance, containing a large quantity of oxygen, is decomposed with great facility; hence it deflagrates with inflammables, and with phosphorus detonates violently. A later view has



been given of the cause of the changes of colour of the solution of the mineral chameleon by Dr Forchhammer. He infers, that they are owing rather to alterations in the state of oxidation of the acid than in the proportion of potash with which it is united; when the red colour passes to green, he conceives that the manganic passes to the state of manganous acid, remaining still combined with the alkali. The former acid he infers to contain 4, and the latter 3 atoms of oxygen to 1 of manganese. It is obvious, that this view differs little from the old opinion, only it will follow, from the absorption of oxygen, that in the mineral chameleon, the metal is in even a higher state of oxidation than in the black oxide. Dr Forchhammer farther states, that he obtained the manganic acid in solution by heating nitrate of barytes with peroxide of manganese, and adding to the compound diluted sulphuric acid. The manganic acid remained in the state of a rich red coloured solution.

Oxide of manganese combines with those earths capable of vitrification, and with their compounds, and communicates to the glasses they form a violet tinge: it communicates the same colour to borax, and other vitrifiable salts. If heated with these fluxes by the blow-pipe, the colour soon disappears in the interior flame from de-oxidation, but appears again if a little nitre be added.

Sulphuret of manganese was obtained by Berthier by heating the sulphate in a charcoal crucible; it was of a grey colour and crystalline appearance. It was also procured by passing hydrogen gas over the ignited sulphate.

Manganese, from its infusibility, cannot be combined with many of the metals. It shews, however, a considerable affinity to iron, occurring frequently combined with it in nature; it is contained too in those ores of iron best adapted to the fabrication of steel, and is supposed to im-



prove the quality of steel. Manganese is applied to no use in its metallic form. The black oxide is employed by the chemist in preparing oxygen and chlorine gases. It has long been used in the art of glass-making, to counteract the green tinge communicated by the iron contained in the materials, an effect it produces by yielding oxygen to the oxide of iron, and bringing it to a high degree of oxidation; in a larger quantity added to glass, it gives a purple colour. It is also used to give a black colour to earthen ware.

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CHAP. XXI.—OF MOLYBDENUM.

THIS metal exists, combined with oxygen and sulphur, in a mineral similar to plumbago in appearance, to which the name of molybdena had been given. Scheele discovered the nature of this substance, and gave processes by which the metal is extracted from it. The most simple, and which also affords the purest product, is to distil from one part of it reduced to powder, five parts of diluted nitric acid to dryness, repeating this distillation three or four times with new portions of the acid. The sulphur is converted into sulphuric acid, the molybdenum into molybdic acid: the former is removed by washing with water, the latter remains undissolved. By calcination too, the sulphuret may be dissipated, and molybdic acid obtained.

The reduction of this acid, or rather the fusion of the metal, is extremely difficult. If exposed to intense heat in mixture with charcoal and oil, the oxygen is abstracted, but the metal is scarcely agglutinated. Hielm, how-



ever, obtained it in a kind of slag; and Bucholz, after repeated experiments with the most intense heat that could be raised by the fire of a forge, succeeded in fusing it so as to obtain it in globules, and even in a mass of two drachms weight. He found it to be of a silvery white colour; it had no ductility or malleability, but was so hard as not to be easily broken: its specific gravity was 8.6.

Though this metal is so infusible, it is easily oxidated: its surface becomes dull from the flame of the blowpipe; and by the application of a red heat, it becomes of a brownish-yellow colour which changes to violet. There appear to be three oxides of molybdenum,—the protoxide, consisting of one atom of molybdenum, 48, and one of oxygen, 8, = 56; the deutoxide, by some termed molybdous acid, composed of one atom of metal, 48, and two of oxygen, 16, = 64; and the molybdic acid, containing one of metal, 48, and three of oxygen, 24, = 72. The protoxide is brown; it may be obtained, according to Dr Thomson, by dissolving molybdic acid in ammonia, evaporating and exposing the dry compound with charcoal powder to a white heat in a covered crucible. The deutoxide may be formed by triturating two parts of molybdic acid with one of molybdenum, in hot water, till the mixture becomes blue; or by heating molybdic acid in muriatic acid, and continuing the heat till the latter acid is driven off: when anhydrous, Dr Thomson states that it is of a purple colour, but when mixed with water is of a beautiful blue. It is soluble, and is said to redden litmus, and to decompose the alkaline carbonates with effervescence: from these acid properties, it has been named Molybdous acid. It appears to combine with salifiable bases; and the molybdic acid, in acting on several bases, seems to pass to the state of this oxide or acid. The third compound of the metal with oxygen is the Molybdic



acid: this is in the state of a yellowish-white powder, having a specific gravity of 3.4. Its taste is sharp and metallic; it is soluble in water, but requires a large quantity for its solution, nearly 1000 parts at  $212^{\circ}$ ; its solution is of a pale yellow colour, has little taste, but reddens infusion of litmus: it is, however, so weak in its acidity, that, according to Berzelius, it unites as a base with the stronger acids. It is melted by heat, forming a vitreous matter, and if heated strongly is volatilized. By the action of inflammable and metallic substances, it is reduced to the blue deutoxide; even the solar light produces this partial de-oxidation, paper immersed in its solution acquiring a rich blue colour from exposure to the rays of the sun. A similar change often happens when it enters into union with the alkalis, and with some metallic oxides; thus, muriate of tin throws down from solution of molybdate of potash a precipitate of a fine blue colour. Molybdate of potash cannot be obtained crystallized: molybdate of soda forms four-sided tables: molybdate of ammonia gives by evaporation a striated yellow mass. Molybdic acid may be combined with metallic oxides by double affinity, and from several metallic salts compounds of rich colours are precipitated by the alkaline molybdates. The molybdates, added even to vegetable colouring substances, improve the richness and permanence of their colours.

Molybdenum is dissolved by nitric and nitro-muriatic acids, and by solution of chlorine. The solutions are of a blue colour; they can scarcely be crystallized without decomposition. Molybdenum combines with sulphur, forming a substance of a flaky texture, similar to the native bisulphuret.



## CHAP. XXII.—OF CHROME.

THIS metal combined with oxygen so as to be in the state of an acid, was discovered by Vauquelin in an ore of lead, the produce of Siberia; it has since been discovered combined with iron in America, and in considerable abundance in Unst, one of the Shetland isles; it appears also to be the colouring principle of the emerald and ruby. Vauquelin gave it the name of Chrome, from its property of assuming brilliant colours in the combinations into which it enters.

It is extracted from the red lead ore, by boiling it with carbonate of potash; the chromic acid which exists in the ore unites with the alkali, forming chromate of potash; by adding a mineral acid, and evaporating, chromic acid is obtained in crystals of a rich red colour. These, by being exposed to an intense heat in mixture with charcoal, are reduced to the metallic state. The ore of this metal, called, but incorrectly, the Chromate of iron, being now procured in considerable abundance from Shetland, is commonly used for obtaining the acid and the metal. This ore is reduced to a fine powder, and exposed to a red heat for an hour or two, mixed with half its weight of nitre. The chrome is converted into chromic acid, and the iron into the peroxide; the chromic acid combines with the potash, and by lixiviation a solution of this salt of a yellow colour is obtained: by the addition of nitrate of mercury, chromate of mercury is precipitated, from which, by exposure to heat, the mercury is volatilized, leaving the green protoxide of chrome. By heating this strongly with charcoal in a crucible, the metal is obtained.

Chrome is of a white colour, inclining to grey; is very



brittle, and displays a radiated structure. It is very difficult of fusion. At a high temperature it is oxidated by the atmospheric air, its surface being covered with a green oxide. It appears to be susceptible of three degrees of oxidation: The protoxide, according to Dr Thomson, consists of one atom of chrome, 28, and one of oxygen, 8, = 36; the deutoxide of one of chrome, 28, and two of oxygen, 16, = 44; and the third, the chromic acid, of one atom of chrome, 28, and three of oxygen, 24, = 52. The protoxide of chrome is usually obtained by heating the chromate of mercury, or it may be procured by adding to a boiling solution of the chromate of potash in water, equal measures of alcohol and strong muriatic acid, until the red tint of the chromic acid disappear, and the liquid becomes of a rich green colour; on adding ammonia in excess to this solution, the protoxide will be thrown down in the state of a hydrate, forming a pale green bulky powder, tasteless, and exceedingly light. The quantity of water which it contains is very large, much exceeding what exists in union with any other metallic oxide. When 33.75 grains of this powder, which appeared perfectly dry, were heated to redness, not less than 29.25 grains of water were expelled from it, only  $4\frac{1}{2}$  grains of the dry protoxide remaining; or adapting these numbers to the scale of equivalents, this hydrate presents the singular combination of one atom of protoxide with 26 atoms of water. It is to the presence of this water that its levity is owing, and it so far modifies the properties of the oxide, as to render it readily soluble in acids, while, when the protoxide is thoroughly dried by a strong heat, it is scarcely acted on by any of the acids. The only salts of chrome are obtained by dissolving the hydrated oxide in acids, or by boiling chromic acid with acids and alcohol. The muriate is of a fine green colour, which may be evapo-



rated to dryness without losing its colour; most of the other salts are soluble; the sulphate, however, is an insoluble powder of a dirty green colour; none of them can be obtained crystallized.

Deutoxide of chrome may be obtained either by heating the nitrate of chrome till the acid is decomposed, and no farther, or by digesting crystals of chromate of soda in alcohol; the salt becomes green, and when dried, and repeatedly digested in nitric acid, the brown deutoxide is produced. It has not hitherto been examined with much care: from its forming brown coloured solutions with alkalis it has been supposed to exert acid powers, and has hence been termed Chromous acid. When a solution of chromate of potash is poured into a fresh solution of green sulphate of iron, a dark brown precipitate falls, which Dr Thomson conceives to be a compound of peroxide of iron with deutoxide of chrome; and from the resemblance which it bears to the chrome ore, he infers the latter to be of similar constitution. From Klaproth's analysis, also, the same conclusion may be drawn, that this ore, commonly called chromate of iron, contains no chromic acid, but is a *bi-chromite* of iron \*.

Chromic acid is obtained usually by mixing solutions of nitrate of barytes and chromate of potash, and digesting the chromate of barytes that is formed in dilute sulphuric acid; this abstracts the barytes, and the chromic acid is

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\* From some experiments which I performed with my friend Mr Edmonstone on the Shetland ore, it appeared very doubtful that the chrome was even in the state of deutoxide; the results rather led to the conclusion, that the mineral contained the protoxide of chrome, or perhaps even was a metallic chromuret of iron.  
ED.



procured by evaporation in crystals of a fine ruby red colour. It is very soluble in water, has a sour metallic taste, and all the characters of a strong acid. The portion of oxygen producing its acidification is not retained by a strong affinity, hence it is easily reduced to the green or brown oxide. Exposure to the solar rays has this effect, as has also the action of metals, or of ether or alcohol, when either of them is boiled with it for a few minutes. Even heat produces this change, the green oxide being formed when the acid is heated before the blow-pipe on charcoal, or with borax.

This acid combines with the alkalis, earths, and metallic oxides, forming salts, many of which have very rich colours. The alkaline chromates are soluble and crystallizable; they are of a yellow or red colour, the neutral chromates being commonly yellow, and the bi-chromates red or deep orange. The best known of these is the Bi-chromate of potash, the most splendid, as Dr Thomson remarks, and one of the most useful of the whole tribe of salts. It is formed by adding to the solution of the chromate of potash, prepared from the ore in the manner that has been stated, nitric or sulphuric acid till the liquid tastes sour; within a day or two the bi-chromate, being much less soluble than the chromate, crystallizes spontaneously in rectangular tables of considerable size, and of a brilliant orange red colour. Its taste is bitter and metallic: it is soluble in 10 parts of water, and the solution reddens vegetable colours. It contains no water of crystallization, and is hence not changed by a red heat: it is composed of one atom of potash, 48, and two atoms of chromic acid, 104; its equivalent is therefore 152. It is now manufactured in large quantities, being extensively used in dyeing, in calico printing, and in the preparation of several valuable pigments. The proper chromate



of potash crystallizes, when pure, in small prisms of a bright lemon yellow colour; it is soluble in twice its weight of water at  $60^{\circ}$ , and to a great extent in boiling water; its taste is bitter and disagreeable; its colour is so intense, that one grain of it dissolved in 40,000 of water gives a yellow tint. Its crystals are anhydrous, and consist of one atom of potash, 48, and one of chromic acid, 52, = 100; though it is thus the true binary chromate, the alkaline properties predominate in it, hence it cannot be called a neutral salt. Chromate of ammonia is in crystalline scales of a fine yellow colour, the bi-chromate of a rich red. Chromate of soda is a beautiful transparent yellow salt, one of the finest of the chromates; it contains 12 atoms of water. The earthy chromates are soluble, with the exception of those of strontites and barytes, and have an orange colour. The metallic chromates have vivid colours,—that of lead is orange, of mercury vermillion, of silver carmine red, of zinc and bismuth yellow. The first of these, the chromate of lead, is now much used under the name of *chrome yellow*, as a beautiful and durable pigment. It is formed by adding solution of acetate of lead to the chromate of potash obtained from the ore: it consists of one atom of chromic acid, 52, and one of protoxide of lead, 112, = 164. Dr Thomson considers it not improbable that a bi-chromate of lead may exist; and this is rendered probable by the fact, that when it is precipitated from a saturated solution of bi-chromate of potash, its colour is much deeper than from a dilute solution. By boiling carbonate of lead with an excess of chromate of potash, a sub-chromate of lead is obtained, consisting of one atom of chromic acid, and two of protoxide of lead: as it possesses a very rich colour, Mr Badams has recommended it for giving a permanent scarlet dye to cotton. Besides these various uses of the compounds of chrome,



the oxide is employed as a colouring substance in porcelain, and in the formation of pastes to imitate the gems.

The discovery of two singular compounds of chrome has been announced by M. Unverdorben,—the Fluo-chromic and Chloro-chromic gases, or rather vapours. The former is produced by heating a mixture of fluor spar and chromate of lead with fuming sulphuric acid in a leaden retort; the fluoric acid rises in vapour combined with a portion of chromic acid, forming a thick yellow or red vapour. This is decomposed whenever it comes in contact with silex or glass, siliceo-fluoric acid gas being produced, and chromic acid deposited. Berzelius collected it in glass vessels coated with resin; but even this did not defend them. It is rapidly absorbed by water, a solution of fluoric and chromic acids being the result. The moisture in the atmosphere occasions the same change in the gas, chromic acid being deposited in minute crystals. Ammoniacal gas introduced into the fluo-chromic vapour burns with explosion. The Chloro-chromic gas, as it was termed by M. Unverdorben, was formed by heating chromate of lead and common salt with sulphuric acid. He described it as a red gas. M. Dumas, however, has lately stated, that the pure chloride of chrome is a liquid, and that it appears in the gaseous state chiefly from intermixture of muriatic acid gas. By passing the gas through a cold tube, the fluid chloride of chrome is obtained. It is of a fine blood red colour, heavier than water, and very volatile, emitting in the air fumes like those of nitrous acid. It acts on mercury and sulphur, and with phosphorus it detonates. It is absorbed by water, being converted into muriatic and chromic acids.

*When poured on ammonia or alcohol it inflames them leaving a green deposit on the sides of the glass*



## CHAP. XXIII.—OF TUNGSTEN.

THIS metal may be obtained from either of two minerals, that named Tungsten, in which its oxide is united with lime, or Wolfram, in which it is combined with oxides of manganese and iron. From the first of these it is extracted by digesting the ore in nitric acid, a yellow powder remaining, which is oxide of tungsten, and which, to render it quite pure, is dissolved in ammonia, and precipitated by nitric acid. From wolfram it is procured by digestion in muriatic acid, which dissolves the iron and manganese; oxide of tungsten remains; it is combined with ammonia by digestion, is precipitated by nitric acid; and the precipitate is calcined with a red heat, by which the adhering acid and ammonia are expelled.

Oxide of tungsten is reduced to the metallic state by exposing it with a little oil in a crucible lined with charcoal to an intense heat. The agglutination of the metal by fusion is, however, extremely difficult. The Spanish chemists, Messrs D'Elhuyarts, describe it as being of a greyish-white colour, with considerable lustre, hard and brittle; its specific gravity they state at 17.6, which is confirmed by the experiments of Aikin and Allen, and by Bucholz; by others it has been stated so low as 8, probably from imperfect fusion.

Tungsten is oxidated when heated under exposure to the air. The white powder obtained by the processes described frequently retains a portion of nitric acid in combination, and hence exhibits distinct acid properties. From this it was denominated tungstic acid, a name still applied to it by many chemists. The researches of Vauquelin, however, have proved, that when perfectly pure it exhibits no acid properties except that of uniting with bases;



hence the name of acid can scarcely be applied to it. As its compounds with bases, however, are well marked, the term of tungstate may be retained as a convenient one, and as it is one generally received. The tungstic oxide or acid is of a yellow colour, insoluble in water, tasteless, and does not change the vegetable colours. By exposure to a strong heat it is partially de-oxidated, and assumes a green colour; when fused with borax, it forms a globule of a blue tinge. Dr Thomson infers the atomic weight of tungsten to be 126, and that the tungstic acid consists of one atom of metal, 126, and three of oxygen,  $24, = 150$ ; others affirm its equivalent to be 120. A brown oxide may also be obtained, containing half the weight of oxygen that exists in the acid.

Tungsten is scarcely sensibly acted on by the acids; even nitro-muriatic acid does not dissolve it. According to M. Wohler, three chlorides of tungsten may be formed: The trito-chloride or perchloride, of a white colour, prepared by heating black oxide of tungsten in chlorine gas; water resolves it into tungstic and muriatic acids: The bichloride, obtained by heating the metal in chlorine; it is in delicate white needles of a red colour: And a third compound, formed along with the bi-chloride, of a fine red colour, fusible, and volatile.

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#### CHAP. XXIV.—OF TELLURIUM.

THIS rare metal occurs alloyed with gold in certain ores of that metal found in Transylvania; when obtained free from alloy, it is of a tin-white colour with metallic lustre, has a foliated fracture, is extremely brittle, and is one of



the lightest of the metals, its specific gravity being only 6.1.

It melts easily, and at a temperature a little inferior to that of ignition; it is also easily volatilized; when heated before the blow-pipe it burns with a blue flame, and an oxide is formed in vapour, having a pungent odour, which condenses into a white powder. This, heated in a glass retort, melts, and forms when cold an oxide of a yellowish colour, and striated texture: this consists, according to Berzelius, of one atom of tellurium 32, and one of oxygen, 8, = 40.

Tellurium is oxidated and dissolved by nitric and nitro-muriatic acids. The solution in the former is colourless, is not rendered turbid by water, and when concentrated, affords needle-shaped crystals: The latter acid affords a transparent solution, from which a white precipitate is thrown down, on the addition of water, and which, by repeated affusions of water, is dissolved. In chlorine gas the metal inflames and forms a white fusible substance, volatile at a high heat. The alkalis throw down from all these solutions precipitates of a white colour, which an excess of alkali redissolves. They are not precipitated by prussiate of potash: tincture of galls forms a yellow flocculent precipitate. Several metals, as zinc, iron, tin, and antimony, precipitate from them the tellurium in its metallic state, and phosphorus has the same effect.

Tellurium combines with hydrogen, and forms with it two distinctly marked compounds. One of these is a solid; it is formed when tellurium wires are employed in connection with a galvanic battery in the decomposition of water; a brown powder falls down from the negative side, which is the *hydruret of tellurium*. The other compound, *telluretted hydrogen*, is procured by acting with dilute sulphuric acid on an alloy of potassium and tellu-



rium, formed by igniting potash and tellurium with charcoal. This gas has a fetid smell, not unlike that of sulphuretted hydrogen: its specific gravity is calculated by Thomson to be 2.2916, to air as 1. It is inflammable, burning with a blue flame, soluble in water, and capable of combining with the alkalis.

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## CHAP. XXV.—OF TITANIUM.

THE oxide of this metal was discovered by Mr Gregor in a ferruginous sand, named Menachanite, from being found in the vale of Menachan in Cornwall. It has since been discovered in Red Schorl, and several other minerals.

The reduction of this oxide by charcoal at an intense heat is extremely difficult. Lampadius obtained the metal more perfectly fused, and found it to be of a copper-red colour with much brilliancy. This result was, however, not free from doubt, and the true metal was not known with certainty till 1822, when Dr Wollaston, examining some small cubic crystals which had been found in the slag of a great iron work in Wales, ascertained them to be this metal. They had the colour and lustre of burnished copper. From iron pyrites, which they somewhat resemble, they were distinguished by their extreme hardness, which was such, that by selecting a sharp angle of one of the cubes, Dr Wollaston found that he could not only write on the hardest steel or glass, but could scratch rock-crystal. Their specific gravity was 5.3: they were slightly magnetic from containing a little iron. They were exceedingly infusible; they were not



acted on by nitric or sulphuric or even nitro-muriatic acids. By continued heat they were oxidated, becoming purple; they were also slowly oxidated when heated with nitre, and more rapidly by the united action of nitre and borax. The product appeared to be the pure peroxide of titanium. Similar cubes have been since found in other iron-works; there appears no reason to doubt that they are metallic titanium.

Two oxides of titanium are inferred to exist. The protoxide is supposed to form the mineral called Anatase. The peroxide is white, and from uniting with a few bases, has been called titanic acid, a character to which it has no other title. It is white, very infusible, and difficult of reduction; it is inferred to consist of one atom of titanium, 32, and two of oxygen, 16, = 48.

The acids act very feebly on titanium: when the stronger acids, however, are boiled on it, they partially dissolve it. The oxide, when fused with carbonate of potash, is more easily dissolved. The solution of nitrate of titanium affords, by spontaneous evaporation, rhomboidal crystals. That of the muriate becomes gelatinous when heated, transparent crystals forming in it when cold. M. Rose, however, supposes, that these solutions are not salts of titanium, but compounds of the peroxide with the alkali. Chloride of titanium has been formed by passing chlorine gas over the cubical crystals heated: a colourless fluid was produced, which emitted dense white fumes, and boiled violently at a little above  $212^{\circ}$ . On the addition of water, solid muriate of titanium is produced.

The alkalis decompose the salts of titanium, throwing down white precipitates, which are probably hydrates or sub-salts. Hydro-sulphurets throw down a greenish precipitate; infusion of galls, one which is reddish-brown. The metals immersed in their solution produce partial de-



oxidation, which gives rise to changes of colour ; a wire of tin produces a bright red, of zinc, a deep blue.

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## CHAP. XXVI.—OF URANIUM.

THIS metal was discovered by Klaproth, forming the principal part of the mineral which had been known by the name of Pechblende ; he afterwards discovered it in other minerals, as that named Green Mica, and in Urانيتic Ochre. It may be extracted from these ores by digestion with nitric acid, which converts the protoxide into peroxide : sulphuretted hydrogen gas is then passed through the solution, which precipitates several of the foreign metals ; ammonia is then added, and the precipitate which falls is digested in solution of carbonate of ammonia : in a few days yellow crystals of a triple carbonate of uranium and ammonia are obtained, from which the protoxide is procured, by exposing them to a red heat. The reduction of the oxide to the metallic form is difficult ; Arfwedson performed it by passing hydrogen gas over the ignited protoxide. The metal is described as of a brown colour, with metallic lustre, and hard, with considerable cohesion.

Uranium is extremely infusible : when heated in the open air it is quickly oxidated, passing to the state of the green protoxide. This oxide is obtained also by heating the perntrate or the percarbonate. It is of a very dark green colour, very infusible, and suffers no change from heat alone. It is dissolved by the acids, forming green salts : ammonia precipitates it from these in the state of a hydrate. Dr Thomson supposes it to consist of one atom



of uranium, 208, and one of oxygen, 8, = 216; but Arfwedson infers the equivalent of uranium to be 216. The peroxide of uranium exists in several of the salts of the metal: thus, when the protoxide is dissolved in nitric oxide, the solution becomes of a yellow colour, from the formation of peroxide. It appears to have considerable affinity to bases, so that it has not been obtained perfectly pure and insulated. It is probably of a yellow colour, as this is the hue of its salts; and it is thrown down by alkalis in the state of a yellow hydrate, retaining a portion of base united with it. From its combining with bases, it has been considered, but with no great reason, as an acid. Dr Thomson supposes it to contain 2 atoms of oxygen, while Arfwedson believes only  $1\frac{1}{2}$  of oxygen to be present in it. By a strong heat it is converted into protoxide.

The oxides of uranium are dissolved by the acids. Those containing the protoxide are green, but are very liable to absorb oxygen, and become salts of the peroxide. The latter are yellow, and, according to Dr Thomson, are usually sesqui-salts: they have also a tendency to form triple salts with any base that may be present. Prussiate of potash throws down from them a brownish-red precipitate, sulphuret of ammonia one brownish-yellow, tincture of galls one of a dark brown. The metals have no effect in decomposing them, a proof of the strong attraction which this metal has to oxygen.

The oxides of uranium are used to give colours to porcelain; the protoxide gives a black, the peroxide a yellow colour



## CHAP. XXVII.—OF COLUMBIUM OR TANTALUM.

THIS is a rare metal, which has been twice discovered, and has received from each discoverer a different name. It was found by Mr Hatchett in a black mineral belonging to the cabinet of the British Museum, which was supposed to have come from Connecticut in North America. By alternately fusing this mineral with potash, and digesting it with muriatic acid, he obtained the metallic oxide or acid in union with the alkali, from which it was separated by nitric acid. He gave to it the name of COLUMBIUM.

Some time after the same substance was extracted by M. Ekeberg, a Swedish chemist, from tantalite and yttrotantalite, two ores from Finland, and gave to it the name of TANTALUM. The identity of these two metals was established in 1809 by Dr Wollaston. Columbium, as the name given by the original discoverer, is certainly the one that should be retained; but Berzelius, and most of the continental chemists, continue to call it Tantalum.

Columbium exists in the Swedish minerals in the state of an oxide or acid, in union with oxides of iron and manganese in the Tantalite, and with yttria in the Yttrotantalite. This oxide is obtained by heating these ores with potash; the oxide forms a soluble compound with the alkali; on adding an acid, as the nitric, it is precipitated in the state of a heavy white hydrate, from which the water may be driven off by a strong heat. Metallic columbium has lately been obtained by Berzelius, by exposing the oxide in a cavity in charcoal to an intense heat: it was of an iron grey colour, having metallic lustre and brittle. It suffered no change from the action of any of the acids,



but was oxidated by fusion with potash. When heated in open vessels it is oxidated so rapidly as to burn, and it deflagrates with nitre.

Only one compound of columbium with oxygen is known,—the white oxide, or columbic acid as it is frequently called, from some weak acid qualities which it possesses. It is tasteless, insoluble in water: as usually procured in the state of hydrate, it is said to redden litmus. Its acid powers, as it was obtained by Mr Hatchett, appeared to be more distinct; but it appears that these arose from the presence of tungstic acid, derived from the accidental intermixture of some tungstate of soda which he had been using. This impurity also rendered it more soluble in acids, and occasioned its giving a blue colour to phosphate of soda by fusion. The pure oxide melts with borax and with phosphate of soda, but does not communicate any colour. It is sparingly soluble in the mineral acids; but the hydrate is dissolved by the oxalic, tartaric and citric acids. It is dissolved by the alkalis, and even by the alkaline carbonates; it does not neutralize the alkaline properties, but the compounds may be obtained crystallized. If as much acid is added to its solution in alkalis, as to neutralize the excess of the latter, infusion of galls causes an orange precipitate; but no precipitation is occasioned by prussiate of potash, or by hydro-sulphuret of potash. Dr Thomson infers the equivalent of Columbium to be 144, and that of its oxide 152.

It is a singular circumstance, that during more than twenty years after Mr Hatchett's discovery, no other specimen containing Columbium was discovered in Connecticut, nor in any part of America; and it has hence even been supposed that the specimen in the British Museum was not American, but probably Swedish. Dr Torry, however, has lately announced the discovery of columbite in a rock at Haddam in Connecticut.



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CHAP. XXVIII.—OF CERIUM.

THIS metal exists in a Swedish mineral, associated with oxide of iron, silex, and lime. Its oxide was extracted by Klaproth, who regarded it as an earth. Hisinger and Berzelius considered it as the oxide of a metal, to which they gave the name of Cerium, though they did not obtain it in the metallic form. The mineral is dissolved in nitro-muriatic acid, and after saturating the solution with an alkali, it is precipitated by tartrate of potash, or by oxalic acid; the precipitate washed, and calcined, is oxide of cerium. It was reduced by Vauquelin to the metallic state by exposure to heat in mixture with lamp-black, oil, and borax, but was obtained in such minute quantity, that the properties of the metal have been imperfectly described. It appeared to be volatile; and by subsequent experiments it has been found to be dissipated by an intense heat.

Two oxides of cerium have been obtained; the protoxide, consisting, according to Thomson, of cerium, 50, and oxygen, 8, = 58; and the peroxide, composed of cerium, 50, and an equivalent and a half of oxygen, 12, = 62. The former is an insoluble white powder, which forms salts with the acids: when heated in open vessels, it is converted into the peroxide, which is of a reddish colour, and is also dissolved by acids. The proto-sulphate of cerium is colourless, and affords white crystals, which have a sweet taste. The persulphate crystallizes in prisms of an orange colour. The proto-nitrate has a sweet taste with some sharpness; it does not easily crystallize. The perntrate is formed with more difficulty, unless heat be applied; the



solution is of a yellowish-green colour ; when there is an excess of acid, it affords crystals by evaporation. Muriatic acid dissolves the red oxide slowly ; the solution evaporated undergoes an irregular crystallization, and affords a deliquescent mass, soluble in water and in alcohol. When it is heated, it burns with a yellow flame. Infusion of galls throws down from its solution a yellow precipitate, and ammonia a brown, which when heated becomes red. These different salts of cerium are decomposed by the alkalis ; precipitates are thrown down, but if an excess of acid be present, triple salts are formed.

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#### CHAP. XXIX.—OF SELENIUM.

THIS singular substance was discovered by Berzelius in 1818, in the sulphur used in a manufactory of sulphuric acid at Fahlun in Sweden. In the chamber in which this sulphur was burnt, he observed a reddish coloured deposite, which when heated gave a strong smell, similar to that of horse radish ; on examining it more minutely, he discovered this substance, Selenium. It had been derived from the copper pyrites of Fahlun, from which the sulphur had been procured : it has since been detected in some ores, and in volcanic minerals, from the Lipari islands.

Selenium is of a grey colour, with metallic lustre when in the mass, but its powder is of a red colour ; it is hard and brittle : its fracture is conchoidal, with a vitreous lustre ; its specific gravity is about 4.6. At  $212^{\circ}$  it softens and becomes ductile, so that it may be kneaded or



drawn into threads of great fineness; these are transparent, and appear of a red colour when held between the eye and the light. When heated in a retort, it is volatilized, and even boils, at a temperature nigh that of boiling mercury, and may be distilled over in metallic drops. By being heated in a large vessel it may be sublimed, condensing in a light sublimate of a fine cinnabar colour. Heated before the blowpipe, or in the flame of a candle, it burns, giving a blue tinge to the flame, and exhaling a very pungent smell, similar to that of horse radish, but much stronger. This smell arises from the formation of a gaseous oxide, and is so powerful that so small a quantity as 1-50th of a grain of selenium will communicate the odour to the air of a large apartment. This gaseous oxide may be obtained by heating selenium in a close vessel. It is colourless, sparingly soluble in water, and has no acid properties; as it is in some degree analogous to carbonic oxide, it may be called Selenic Oxide gas. It is inferred to consist of one atom of selenium, 40, and one of oxygen, 8, = 48.

Selenium is dissolved by nitric and nitro-muriatic acids. The salts of selenic acid are called Seleniates, and those in which there are two atoms of acid Bi-seleniates. The alkaline seleniates crystallize with difficulty, and attract moisture from the air; that of ammonia is decomposed by heat. The seleniates of barytes and lime are soluble in water. If a plate of zinc be introduced into a solution of a seleniate, and muriatic acid added, selenium is precipitated in red flocculi.

When the solution is evaporated to dryness, a white mass is obtained, which is a compound of selenium with two atoms of oxygen. As it possesses distinct acid properties, it is named Selenic acid. This acid crystallizes in four-sided prisms, which attract moisture, have a sour



taste, and are very soluble in water and alcohol: selenic acid is sublimed by heat. It is readily decomposed by substances having an affinity to oxygen; thus, if a rod of zinc is introduced into a solution of selenic acid in muriatic acid, selenium is precipitated in red flocculi. When sulphuretted hydrogen gas is passed through solution of selenic acid an orange precipitate falls, which is a sulphuret of selenium. It melts at a little above  $212^{\circ}$ , and may be sublimed in close vessels; exposed to the air, it takes fire when heated, producing sulphurous and selenic acids: nitro-muriatic acid converts it into sulphuric and selenic acids.

Selenium combines with the alkalis, forming selenurets of a red colour. It is dissolved by oils; the solutions have no hepatic smell. Selenium unites with the metals, the combination being usually attended with the phenomena of ignition. These alloys are commonly of a grey colour, with metallic lustre. The compound of selenium with potassium dissolves in water with effervescence. The acids disengage selenuretted hydrogen gas from it, which has a smell when diluted similar to that of sulphuretted hydrogen, but intolerably offensive; this gas is soluble in water, combines with the alkalis, and precipitates metallic salts, of a dark colour. In these, and other respects, Selenium bears a strong resemblance to sulphur. It seems indeed to form the link connecting the simple inflammables with the metals. Like the former it softens by a moderate heat, and becomes ductile; it is a very imperfect conductor of heat, and a non-conductor of electricity. With the metals it is connected by its great specific gravity, its metallic lustre, and the greater number of its chemical properties.



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## BOOK VII.

### OF MINERAL COMPOUNDS.

THE method of classification which I have followed being founded on analogies in chemical constitution and properties, I have in conformity to it placed together, under the appellation of MINERAL COMPOUNDS, and as forming a distinct class, substances which are in these respects closely connected. They are those compounds, chiefly of earths and metals, which occur in nature, forming the principal products of the mineral kingdom.

The characters of these, as objects of chemical science, are rather peculiar. From the nature of their composition, and still more from the state of aggregation, they exert scarcely any important chemical agencies, and display few striking chemical properties; in no case do they enter into chemical combination, and their history is thus in a great measure limited to the description of their physical qualities, and to the account of their constitution, so far as this has been discovered by analysis.

From these peculiarities it has happened, that these substances have frequently been regarded as objects of mere description, and hence as belonging to a different department of knowledge from Chemistry,—to Mineralogy, the object of which is to describe with accuracy the external appearance and properties of minerals, and by these to discriminate them from each other. But still they also fall within the province of chemistry; they are,



in common with all natural bodies, objects of its investigations, with the view of discovering their composition; and it is only on this composition that their proper specific distinctions can be established.

It has been attempted, indeed, to establish the species of minerals on other grounds; and in particular it has been assumed, that an identity in their crystalline structure, or an agreement in their external qualities, is sufficient to unite under one species those minerals in which it is observed. Those two characters form the basis of the mineralogical systems at present received: the one of the system of Häuy, the other of the system of Werner.

In the latter system, the species of minerals are founded on an agreement in their external properties, those being considered as forming a species, in which an identity, or at least a strict analogy in the most essential characters exists: and this principle frequently regulates the classification, in opposition even to the results of chemical analysis. So far as the properties of bodies are connected with their chemical constitution, a correspondence in the one way may no doubt be considered as denoting a similarity in the other. But differences of external properties do not always denote an essential difference of nature; they often arise from other sources, and in minerals particularly, from slight and unimportant intermixture of accidental ingredients, or even often merely from the state of aggregation. Hence by attending to such differences alone, substances essentially the same are regarded as specifically different; what are mere varieties are ranked as species; and without the light which chemistry reflects, mineralogy would from this cause soon include many inaccurate distinctions.

The other character,—that connected with the internal structure of minerals, which has been assumed as a basis



of their specific distinctions, is founded on a discovery, already noticed, (vol. i. p. 31.) made by Haüy, the celebrated French mineralogist, that in every crystal there exists a nucleus of a certain geometric form, capable of being extracted from the crystal by mechanical division. This nucleus, or primitive form, he farther found to be the same in the various crystals of one substance, however diversified their figure might be; he hence inferred, that it indicated identity of species, and afforded a just ground for the specific distinctions of minerals. Its insufficiency, taken by itself, however, is evident from the fact, that the same primitive form has been found in different substances; and there is therefore still the necessity of chemical analysis, or of some other principle, to determine its application. And the character, were it admitted, is not applicable to those minerals which do not occur in a crystallized state, though there are many such well defined as species, and of determinate chemical constitution.

The only proper basis of a species in mineral bodies is chemical composition. It is this which is the source of all their essential properties, and which properly establishes the identity of two substances; and however useful characters from properties may be in recognising these substances, as affording specific distinctions they are altogether arbitrary and artificial. In organised bodies, there is a different ground of distinction,—the peculiar organization and form of each individual as a living being, and the power of transmitting these, or of producing a similar being. But in the mineral kingdom this is altogether wanting, and nothing remains equally determinate but the chemical composition; nor can any other circumstance constitute an essential agreement in two unorganized substances.



It is to be admitted, however, that the specific composition of minerals is not always easily determined, so as to admit of a method strictly chemical being followed. They usually consist of several principles combined, and diversities of properties are established from differences of proportions frequently minute, or even from mere differences in the state of aggregation. Ingredients, too, are often contained in them which are not essential to the composition. Hence it is often difficult to establish an identity of composition among minerals which have evidently a strict resemblance in external qualities, or to unite the varieties of a species by the results of their chemical analysis.

From these circumstances it is necessary, in fixing the mineral species, to adopt a less rigorous method. A certain combination may be understood to constitute a species, and this can in many cases be unequivocally determined, as in all those in which an earth and an acid are united together. There are others in which the composition is more complicated, and in which it is more difficult to determine what constitutes the specific composition, as where the analysis discovers four or five ingredients, united perhaps in different varieties of the fossil in different proportions. In these cases, the difficulty is often such, that it is necessary to have recourse to other sources of distinction : these are drawn from the external properties of the substances, or from the structure as developed in their crystalline forms ; and thus many of the species at present received in mineralogical systems are established as much on these distinctions as on the chemical composition.

It is only to be understood, that these methods are provisional and subordinate. A peculiar composition no doubt constitutes every natural species, which will in time



be discovered in all ; and when discovered, will properly define the species. From the perfection of the present methods of chemical analysis, we have even every reason to believe, that in no long period this fundamental department of Mineralogy will be fully investigated, and the classification of minerals from their composition rendered complete. And this is the more probable, as the important fact has been established by the labours of Berzelius and other distinguished analysts, that the doctrine of definite proportions applies in its full extent to the constitution of much the greater number of mineral substances which have yet been examined,—That most minerals, even those of very complicated composition, are not, as was before believed, irregular mixtures, which could scarcely be included in any strict chemical arrangement, but compounds as definite as the neutral salts ; their ingredients being combined in proportions exactly conformable to their atomic weights. Even with respect to minerals in which these exact proportions are not at first view apparent, by distinguishing their constituents into those which are essential, or on which their crystalline forms and chief properties depend, and those that are adventitious, or which are present in variable quantity, are sometimes altogether absent, and are frequently, as Berzelius has shown, replaced by other foreign substances, we are enabled to classify them also with as much facility as those of simpler constitution. The view thus developed of the nature of mineral bodies, is highly favourable to the opinion which has been stated as to chemical composition being the true basis of mineralogical arrangement. This application of the atomic doctrine to analysis, supplies also what was before so much wanted, namely, a directing general principle, which may, to a certain extent, guide the chemist in his researches, and



which he can at all times employ as a check upon his calculations and results, in correcting accidental errors, and determining minute differences of numbers with absolute precision.

The classification of minerals is thus to be regarded as essentially chemical. Each earth, or each metal, forms a genus, under which are arranged as species the particular fossils in which it predominates; the native saline compounds, as well as the mineral inflammables, are arranged on a similar principle. And under all these genera the species are established, as far as the imperfect state of the science admits, on identity of composition.

It is obvious, that in thus considering the description of minerals as subservient to their chemical relations, those minute details of external qualities and appearances which belong to a strictly mineralogical work, are in a great measure excluded. It is sufficient to enumerate the more important and characteristic properties, those which unite the varieties of the species, and serve to distinguish it from others. It is in conformity to this principle, that I have given the brief mineralogical descriptions in the following chapters. It is equally evident, that in conformity to these views, a place can be given to those minerals only which have been fully examined, and are well defined. In general, also, it would occupy too much space to give the exact chemical constitution of every body, as in many of them there are not less than five or ten ingredients. As most of the compounds of the earths and metallic oxides with acids do not differ much from the artificial compounds which have been already described, their constitution will be learned with sufficient certainty, by looking back to the history of the different bases that have been noticed, or by inspecting the table of definite combinations at the end of this volume.



The appearances and characters of minerals being of importance in describing and distinguishing them, it has become necessary to employ mineralogical language with much precision; and hence all the terms employed to denote the external appearance of minerals have been exactly defined. A complete view of this language would be inconsistent with the limits of this treatise; and the subject being not strictly chemical or elementary, I refer for an abstract of it to my larger System, or to the treatise by Professor Jameson on the External Characters of Minerals. The crystalline forms, simple or modified, have been already described in vol. i. p. 38.

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#### CHAP. I.—OF SALINE MINERALS.

UNDER this order may be placed those substances which have the general characters of salts,—are sapid, soluble in water, and crystallizable. The principal of these are a few alkaline salts, and one or two acids which are found native.

NATIVE ACIDS.—The Boracic Acid has been discovered in solution in certain hot springs in Tuscany, at the edges of which it is found in stalactitic incrustations. It has since been found in some volcanic products from the Lipari islands, and in incrustations on the sulphur within the crater of Vesuvius. It is distinguished by its acidity, its easy fusibility, and its communicating to flame a green tinge.

SULPHURIC ACID has been discovered in the glacial state in volcanic fissures, owing its concrete state to the presence of sulphurous acid.



SALTS.—MURIATE OF AMMONIA is sometimes found as a product of volcanoes, or pseudo-volcanoes, being probably formed by the action of heat on substances containing its elements, and sublimed, in the form of an efflorescence, loose and flaky; sometimes also massive, tuberosc, or even indistinctly crystallized; it is easily recognised by its chemical properties.

NITRE, or NITRATE OF POTASH, occurs as an efflorescence on the surface of the ground in warm and dry climates, on soils strongly impregnated with vegetable and animal substances. It sometimes too forms an efflorescence on limestone rocks; it is distinguished by its cool taste, and by the deflagration it excites in burning fuel.

SULPHATE OF SODA is a frequent ingredient in mineral springs; it is sometimes deposited at the sides of salt lakes, or as an efflorescence on the soil in their neighbourhood.

CARBONATE OF SODA is found native in the form of an efflorescence on the surface of the ground in different countries, particularly in India: in some of the interior districts in Africa, it occurs in crystalline layers or deposits; and in Egypt and Hungary, it is dissolved in the water of certain lakes, from which, in the dry season, it is deposited. In all these cases it is associated with sulphate and muriate of soda; and from the description given by the French chemists of the lakes in Egypt, and the nature of the surrounding rocks and soil, it appears to be derived from the infiltration of water, holding muriate and sulphate of soda dissolved, through a bed of carbonate of lime; the muriatic and sulphuric acids being probably abstracted by the lime, and the carbonate of soda removed by efflorescence, so that the re-action of the muriate of lime on it is obviated.

MURIATE OF SODA or CHLORIDE OF SODIUM is the most abundant saline product of the mineral kingdom, being



found in immense deposits, besides what exists in mineral springs, and in the water of the ocean. In the former state it is the Rock Salt of Mineralogists. It is in crystalline masses, more or less transparent, colourless, or of a grey or reddish colour, with vitreous lustre, and having a taste purely saline: its fracture is foliated, sometimes fibrous, and its fragments are cubical. It is usually pure, or contains only a very minute quantity of foreign saline matter. Its beds are connected with rocks of secondary formation, and more particularly with gypsum, limestone, and sandstone.

BORAX, or BI-BORATE OF SODA, it has already been stated, is found in Thibet, being deposited from the water of a lake in which it is dissolved, in crystalline masses, of a greenish colour, and semi-transparent, with vitreous lustre, having a foliated fracture. There appears to be a constant reproduction of it, as, although it has been long dug, there is no appearance of it being exhausted; but of its origin nothing is known.

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#### CHAP. II.—OF EARTHY MINERALS.

UNDER this order are placed those fossils in which the earths are the principal ingredients, though with these are often combined saline and metallic substances. It is subdivided into genera, according to the earth which enters principally into the composition; and under each genus the species containing this earth are arranged. The earthy fossils are in general tasteless, insoluble in water, unflammable, and of moderate specific gravity.



SECT. I.—*Of Barytic Minerals.*

UNDER this genus there are only two species, the Sulphate and the Carbonate. They are distinguished from other earthy fossils by their greater specific gravity.

SULPHATE OF BARYTES.—The Heavy Spar of mineralogists forms several sub-species. The Lamellar, or Foliated, occurs often crystallized: the forms of its crystals are numerous, but are all reduced to the oblique four-sided prism, and the rectangular four-sided table, perfect, or modified by truncation or bevelment of the edges or angles. The colour is white, frequently with shades of grey, yellow, brown, or red; the lustre shining, intermediate between pearly and vitreous; it is transparent, when massive often only translucent: its fracture is foliated, straight or curved. It is scratched with the knife, is brittle and heavy. It melts before the blowpipe into a white enamel. The other varieties are unimportant. Granular Heavy Spar presents a fine foliated fracture, and contains 10 *per cent.* of silex. Compact Heavy Spar has a fracture fine grained uneven, passing into earthy; has less lustre; is only translucent on the edges; is sometimes earthy and dull. Columnar Heavy Spar derives its name from the appearance of its masses, which are composed of oblique four-sided prisms, aggregated in a columnar form. Bolognian Heavy Spar occurs in rounded masses, and presents a radiated fracture.

CARBONATE OF BARYTES occurs massive, in globular pieces, and sometimes, though rarely, in crystals which are six-sided prisms acuminate by six planes, and double six-sided pyramids; its colour is white, with a shade of grey; it is translucent; its lustre is shining; its fragments are wedge-shaped; its specific gravity is 4.3. It dissolves with effervescence in diluted nitric acid.



SECT. II.—*Of Strontitic Minerals.*

THE natural species of this genus are those in which the earth is mineralized by sulphuric and by carbonic acids. The SULPHATE, Cœlestine, occurs massive, and crystallized in six-sided tables, or in rhomboidal four-sided prisms acuminated by four planes: their colour is milk-white, with a shade of blue; they are semi-transparent: when massive it is nearly opaque: its lustre, when crystallized, is shining; when massive, it is dull. Its fracture is foliated, or fibrous; the specific gravity is 3.5.

The CARBONATE is usually massive: sometimes from the mass slender crystals shoot, which are six-sided prisms acuminated by six planes. Its colour is light green; its lustre shining and pearly; its fracture radiated; its specific gravity 3.6. Before the flame of the blowpipe it becomes white and opaque, but is not fused: it dissolves in diluted nitric acid with effervescence. According to Dr Hope's analysis of it, it consists of strontites 61.21, carbonic acid 30.2, water 8.59.

BARY-STRONTIANITE, or STROMNITE, is a mineral discovered by Dr Traill, in a lead-mine near Stromness in Orkney. It consists chiefly of carbonate of strontites, containing, however, a large proportion of sulphate of barytes, probably chemically combined with the carbonate. It occurs in masses, having some appearance of disintegration; of a greyish colour, with a weak pearly lustre, translucent at the edges; it is soft and brittle, and its specific gravity about 3.7. By acids it is partially dissolved with effervescence.



SECT. III.—*Of Calcareous Minerals.*

THE fossils which belong to this genus consist of lime in combination with different acids.

SULPHATE OF LIME forms the Gypsum of mineralogists. Four varieties have been distinguished,—the Earthy, Compact, Fibrous, and Foliated. The first occurs slightly indurated; of a yellowish or greyish-white colour; dull and meagre to the touch. Compact Gypsum is the substance named Alabaster, which is used for statuary. It is massive; its fracture is even, its colours are usually shades of grey: it has little lustre, but acquires it when polished. Fibrous Gypsum occurs massive: its fracture is fibrous, the fibres being straight or curved, and parallel: its colour is white, grey, yellow, or red: its lustre shining and silky: it is translucent, and so soft as to be scratched by the nail. The Foliated Gypsum or Selenite occurs massive and crystallized, in oblique six-sided prisms, bevelled, or acuminate by four convex planes at each extremity; when the prism is wanting, these planes united form a spherical convex lens. Its lustre is shining, generally pearly: it is, when crystallized, transparent; when amorphous, translucent, its fracture is foliated; sometimes diverging radiated: it is easily split: is soft, so as to be scratched by the nail: has a specific gravity of 2.3.

All the varieties of native sulphate of lime have nearly the same chemical characters. They lose their transparency before the flame of the blowpipe; they are soluble in sulphuric acid, when its action is aided by heat. Selenite, which is the purest variety, consists of lime 32, sulphuric acid 46, water 22. There is also a native sulphate of lime, into the composition of which water does not enter, and which perhaps forms therefore a distinct spe-



cies. It has been named Anhydrous Gypsum, and differs from the other in its forms of crystallization, and in being harder. The Cube Spar of Werner is an anhydrous sulphate of lime. What has been named Glauberite, which occurs in oblique four-sided prisms, transparent and shining, is composed of sulphate of lime with sulphate of soda, both free from water.

CARBONATE OF LIME occurs in different states, from differences in its aggregation, and from the intermixture of other substances. There is hence considerable difficulty in arranging its varieties, and in determining whether some of them ought not to be regarded as distinct species.

CRYSTALLIZED CARBONATE OF LIME.—The calcareous Spar of Mineralogists is the species in the purest state. The forms of its crystals are the six-sided pyramid, three-sided pyramid, and six-sided prism: with numerous modifications from combination, acumination, bevelment, and truncation, giving rise to an almost unlimited variety of secondary forms: the crystals are generally transparent, or semi-transparent: they have very distinctly the property of double refraction, or a dark line seen through a crystal appears double: the lustre is shining, vitreous, or sometimes pearly: the colour is white, sometimes grey, green, red, yellow, and light purple. The fracture is foliated, with a threefold cleavage: the fragments are rhomboidal: it can be easily scratched with a knife: it is brittle: its specific gravity is 2.7. It decrepitates before the flame of the blowpipe, but does not melt; effervesces strongly with the acids, and is entirely soluble in diluted nitric or muriatic acid.

FIBROUS CARBONATE OF LIME occurs massive, or in imitative shapes; the stalactites deposited from water holding carbonate of lime in solution, belong to it; but it also occurs, not of stalactitic origin, in veins. Stalactitic car-



bonate of lime is, from the nature of its formation, presented under various forms, conical, tuberosc, coraliform, and botryoidal. Its usual colour is white: its lustre weakly shining; it is translucent; its fracture fibrous, the fibres being generally divergent; it is softer than calcareous spar. Pisolithe, or Peastone, so named from the mass being composed of small rounded concretions like peas, appears to be of a similar origin. Roestone is probably connected with this. It is in small globular concretions, dull, opaque, of a brownish colour, and soft.

GRANULAR CARBONATE OF LIME, or GRANULAR LIMESTONE, occurs massive, and in strata, generally connected with primitive rocks, and hence receiving the name of Primitive Limestone. Its fracture is small foliated, sometimes splintery; its colours white and grey; its lustre is intermediate between pearly and vitreous; it is translucent; is harder than calcareous spar, and less brittle. It effervesces with acids. It appears often to be carbonate of lime nearly pure, but it also contains silex, argil, and magnesia, in variable proportions. It furnishes some of the finest marbles, and particularly those which are used for statuary.

COMPACT CARBONATE OF LIME, or COMPACT LIMESTONE, is carbonate of lime much less pure, other earths being present in considerable proportion. Its fracture is compact, generally small scaly, passing into uneven or earthy: its usual colour is grey: it is dull, and a little translucid on the edges. It occurs always massive, generally regularly stratified, and in connection with other secondary strata, and often contains in abundance the remains and impressions of organic beings, particularly of marine animals. It is in common use for burning into lime, and when of a fine grain, is sometimes polished as marble.



EARTHY CARBONATE OF LIME includes Chalk and Marl. Chalk is the carbonate nearly pure, deriving its external characters from its state of aggregation. It occurs massive, generally in beds: its fracture is earthy; its colour white or yellowish, dull, and opaque; is so soft as to soil. It dissolves in acids with effervescence. Marl is an impure carbonate in a loose state of aggregation. It is composed of earthy particles, more or less indurated, is dull, and feels meagre; it effervesces with acids, and generally falls to powder in water, or under exposure to atmospheric air. The Bituminous Marl Slate is more highly indurated, and has a slaty fracture. It occurs stratified, and is distinguished by frequently having impressions of fish.

There remain some fossils, in which carbonate of lime is chemically combined with other principles, and which properly constitute distinct species.

Arragon Spar, or Arragonite, presented for some time a peculiar difficulty in mineralogy. It appeared from the most accurate chemical analysis, to consist only of carbonate of lime, yet it differs from calcareous spar in some essential characters. Haiiy found that the cleavage was different, indicating a different crystalline arrangement, and a difference in the primitive forms of the crystals; it is also much harder and heavier. It occurs crystallized in six or four-sided prisms, or double six-sided pyramids, frequently acicular, white, or with shades of grey or yellow, usually transparent, having a high vitreous lustre; brittle, its fracture is foliated with a fourfold cleavage, uneven, or radiated. Stromeyer discovered that it contains carbonate of strontites, along with carbonate of lime, the quantity being from 2 to 4 in 100 parts. To this its peculiar characters must be ascribed.

Pearl Spar, or Brown Spar, is carbonate of lime, with



carbonates of iron and manganese ; it occurs massive and crystallized ; its forms being the rhomb, the lens, and the double three or six-sided pyramid : its colours are white, with shades of grey, yellow, or red ; from exposure to the air, the colour darkens, and becomes brown. Its lustre is shining and pearly ; it is translucent ; its fracture is curved foliated ; it is rather heavier and harder than calcareous spar : it blackens before the blowpipe ; effervesces with acids, but not strongly. Its composition is variable with regard to the proportions of magnesia, iron and manganese. It usually contains above 50 of carbonate of lime ; with this is associated carbonate of magnesia, and the metallic carbonates from 3 to 30. When they are in large proportion, it forms Sparry Iron Ore. The manganese appears to exist in it at the *minimum* of oxidation ; and by absorbing oxygen, causes the deepening of the colour from exposure to the atmosphere.

Rhomb Spar, or Bitter Spar, consists of carbonate of lime with carbonate of magnesia, and a little oxide or carbonate of iron and oxide of manganese. It occurs crystallized in rhombs, is semi-transparent, or translucent ; has a shining lustre, and is of a white or grey colour. Its fracture is foliated ; its fragments are rhomboidal ; it is harder and heavier than calcareous spar ; and it does not effervesce with acids unless it is in powder. I found one variety of it, well defined in its characters, to consist of 56.6 of carbonate of lime, and 42 of carbonate of magnesia, with small portions of iron and manganese. But in different varieties the proportions of the two carbonates are very variable. The variety of Limestone named Dolomite seems to be the same species in a massive form. And the Magnesian Limestone which occurs in extensive beds, is of similar composition.

Slate Spar, or Argentine, occurs massive ; has a high



pearly lustre; is translucent, and of a white colour; its fracture is foliated: its fragments are slaty, or wedge-shaped; is soft; it effervesces strongly with acids. Heated, it becomes brown, and may be fused into a brown porcelain. It contains a portion of oxide of iron, or of manganese. It passes into what is named Silvery Chalk, or Schaum Earth, which has the same pearly lustre and colours.

Fetid Carbonate of Lime, Lucullite, or Swinestone, according to Vauquelin, is carbonate of lime impregnated with sulphuretted hydrogen, whence it emits an unpleasant odour, when rubbed. It occurs massive; of a brown colour, with little lustre. It burns into lime.

PHOSPHATE OF LIME presents different varieties, which can be connected only by chemical characters. What is named Phosphorite is found massive in extensive beds, in an earthy or little indurated state. Its colour is yellowish or greyish white; it is dull, opaque, and rough to the touch. It is highly phosphorescent when heated or rubbed. Apatite is another variety. It occurs generally crystallized in equiangular six-sided prisms, which are seldom acuminate; its colours are white, green, blue, and red, generally pale; it has considerable lustre and transparency; the fracture is imperfectly foliated; the hardness moderate. When thrown on burning fuel, it gives a greenish phosphoric light. It consists of an atom of lime, 28, and one of phosphoric acid, 28, or of equal parts of these ingredients.

There is still a third variety, which, from its lustre and transparency, had been even ranked as a gem, being regarded as a variety of chrysolite. Vauquelin was surprised to find it composed of phosphoric acid and lime; and the proportions are the same as in the apatite. Its



characters are similar, only its colour is a fine asparagus green, whence it has been named Asparagus Stone, and it has much more lustre and transparency. It is soluble in nitric acid, and in diluted muriatic acid; but is not phosphorescent.

FLUATE OF LIME, or Fluor Spar, is found massive, and crystallized; the forms of its crystals are the cube, perfect, or modified by truncation of the angles or edges, bevelment of the edges, and acumination of the angles by three or by six planes. Its colours are numerous, principally shades of purple, yellow, green, blue, red, and grey, and often intermixed: the lustre is resplendent, and is vitreous: the transparency from perfectly transparent to translucent: the fracture is foliated; it is scratched by the knife, but it scratches calcareous spar: it is brittle: its specific gravity is 3.2. Exposed to the flame of the blowpipe, it decrepitates, and then melts into an enamel: on burning fuel, or on a red-hot iron, it gives a beautiful purple light, and is also phosphorescent from friction. The variety named Compact Fluor is distinguished principally by its fracture; it is always massive, has less lustre than the foliated, and is only translucent.

SILICEOUS BORATE OF LIME, or DATHOLITE, occurs massive and crystallized in oblique four-sided prisms, having a shining resinous lustre; of a white colour, translucent, with an uneven fracture. Before the blowpipe it melts with intumescence. It consists, according to Klaproth, of 36.5 of silica, 35 of lime, 24 of boracic acid, and 4 of water. The mineral named Botryolite, from its occurring in botryoidal masses, is of similar composition, containing only 13.5 of boracic acid.



SECT. IV.—*Of Magnesian Minerals.*

UNDER this genus are comprehended those fossils in which magnesia is the ingredient present in largest proportion, and also those in which, though in smaller proportion, the characters peculiar to it exist, those in particular of softness and apparent unctuousity.

Under the name of Native Magnesia, several fossils have been described, in which magnesia predominates, with more or less intermixture. The purest is a Hydrate of Magnesia, found in New Jersey in North America, described and analysed by Dr Bruce. It occurs in layers of a foliated structure; the thin plates are transparent; its colour is greenish-white, its lustre pearly; it is soft, adheres slightly to the tongue, and has a specific gravity of 2.1. From Dr Fyfe's analysis, it appears to be composed of one atom of magnesia, 20, and one of water, 9. Carbonate of magnesia occurs massive, and in tuberosc pieces, of a yellowish-grey colour; it is dull, feels meagre, is soft; has a conchoidal fracture. It consists of an atom of acid, and one of magnesia, with a little water, and siliceous earth. Meerschaum, of which the Ecume de Mer tobacco pipes are made, was supposed to contain carbonate of magnesia; but Berthier has found it to consist of silex 50, magnesia 25, and water 25. Its colour is yellowish-white; its fracture earthy; it is very soft, and feels greasy; it forms a viscid paste with water; is not melted by the heat of the blowpipe, nor does it effervesce with acids.

STEATITE, named also Soap Rock, from its softness and feeling soapy, occurs massive. Its colour is greyish, greenish, or reddish-white, with little lustre: its fracture is coarse scaly: it is soft, or very soft; feels unctuous—



does not adhere to the tongue. It does not melt before the blowpipe, but becomes white and very hard. The proportions of its constituent parts vary. It appears to be essentially a compound of magnesia and silica, with smaller quantities of water, argil, and iron.

POTSTONE is allied to steatite. It occurs massive; is grey, greenish or reddish, dull, and opaque. Its fracture is imperfectly slaty: it is soft, and feels unctuous. It is infusible before the blowpipe, and hardens in the fire. It consists of hydrated carbonate of magnesia with silex and oxide of iron.

SERPENTINE derives its name from the variegated disposition of its colours. The principal colour is green, but with this are intermixed, in stripes or specks, other colours, particularly red. It is opaque, and has no lustre, though it acquires it when polished. Its fracture is splintery; it is easily scratched by the knife: it feels soft, but with little unctuousity. It always occurs massive, and forms entire rocks. It consists of from 30 to 40 *per cent.* of silex, and from 37 to 47 of magnesia, with 10 or 15 of water, and smaller proportions of lime, alumina, iron, manganese, and chrome.

Schillerspar seems to be allied to serpentine. Its colour is dark green: its lustre shining, and varies according to the position with regard to incident light; its fracture is foliated: it is soft.

CHLORITE.—Of this fossil there are several varieties, differing in the state of aggregation. Common Chlorite occurs massive and disseminated. Its colour is dark-green; its lustre weakly shining; it is opaque: its fracture is earthy; it feels meagre. Foliated Chlorite is of a curved foliated fracture, occurs massive and disseminated, and also crystallized in six-sided tables; its colour is dark-green, its lustre pearly, inclining to resinous; it is



translucent on the edges; is soft, and feels rather unctuous. Chlorite Slate, distinguished by its slaty fracture, forms a mountain-rock; its colour is dark-green; it is opaque, and soft. Earthy Chlorite is composed of small scaly particles, of a dark-green colour; feels rather greasy; and when breathed on, gives an earthy smell. Green Earth, as it is named, which occurs incrusting the agate balls in amygdaloid, or filling the cavities of the rock, is similar to Earthy Chlorite.

TALC occurs massive, disseminated, and in small tabular crystals. Its colour is greenish, or yellowish-white, with considerable lustre; it is sometimes transparent in thin leaves; its fracture is foliated; the plates into which it is divisible are flexible, but not elastic; it is unctuous to the touch. It is infusible before the blowpipe, but is melted in the heat excited by oxygen gas. It consists of silex from 50 to 60, magnesia from 27 to 44, and small portions of alumina and oxide of iron. Indurated Talc occurs massive; its fracture is slaty; it is less soft and greasy than the common talc, and has less lustre. Earthy Talc is in small scales, of a pearly lustre, friable, soiling a little, and feeling unctuous. The *Craie de Briançon*, or French Chalk, seems to be a variety of this.

ASBESTOS.—To this species belong several varieties. Common Asbestos occurs massive; its colour is green or grey; its lustre is weakly shining; its fracture is fibrous or radiated; it is soft or semi-hard, and its fibres are rigid. Silex and magnesia are the chief ingredients, with smaller portions of lime, alumina, and oxide of iron. AMIANTH is a variety of the same species, distinguished by its texture being more delicately fibrous, so that the fibres are easily separated, are fine and flexible. It has also greater lustre, which is pearly or silky; its colour is lighter, and sometimes it is silvery white. It is this sub-



stance which was employed by the ancients to form an incombustible cloth to collect the ashes of the dead on the funeral pile. This cloth has been imitated by weaving the fibres of amianth with flax, and afterwards burning out the latter. Ligniform Asbestos is that variety in which, in colour and texture, there is a resemblance to wood. MOUNTAIN CORK is another variety, perfectly similar in composition. It is in flat pieces, of a grey colour, dull, and opaque; its fracture is fibrous, the fibres being short, and interwoven; is a little flexible; feels meagre, and is so light as to float on water. When its texture is more close, and it occurs in thinner pieces, it is named Mountain Leather.

ACTYNOLITE.—Of this species there are three varieties,—the Asbestous, the Common, and the Glassy Actynolite. Asbestous Actynolite occurs massive, or more rarely in capillary crystals. Its fracture is fibrous; its colour greenish-grey; its lustre shining, and silky. It is opaque and soft. Common Actynolite occurs massive; its colour is green, usually dark; the external lustre is shining; it is translucent; its fracture is radiated; it is hard so as to scratch glass; and is brittle. It is composed of silex 64, magnesia 20, argil 2.7, lime 9.3, iron 4. GLASSY ACTYNOLITE occurs massive, and crystallized in rhomboidal four-sided prisms: its colour is green, passing into greenish-white: its lustre is shining and vitreous; it is translucent; its fracture is fibrous; it is brittle, and moderately hard: it melts at a high heat into a glass. It consists of silex 56, magnesia 24, lime 10, oxide of iron 4.3, with small quantities of alumina, potash, oxides of chrome and manganese, carbonic acid, and water. Granular Actynolite is of a grass-green colour; is slightly translucent; internally shining; its fracture is foliated. The Diallage of Haüy, and the Smaragdite of Saussure,



seems to be the same mineral, with slight differences in the characters. The Hyperstene, or Labrador Hornblende, and the Bronzite, are regarded by Häuy as varieties of diallage. The Hyperstene occurs imbedded in Labrador Felspar, and in Saussurite, of a yellow or red colour, and semi-metallic lustre. They all contain silica, magnesia, and iron, as the chief ingredients. The common diallage contains also chrome. Anthophyllite contains less iron, and a portion of alumina. It is distinguished by its lustre being less metallic, and its specific gravity less.

TREMOLITE comprehends three varieties,—the Asbestous, the Common, and the Glassy Tremolite. The first occurs massive; its colour is white; its lustre weakly shining, and silky; its fracture fibrous; it is very soft, and brittle. Common Tremolite occurs massive, or crystallized in oblique four-sided prisms, bevelled or truncated on the lateral edges, and promiscuously aggregated. Its colours are greenish, reddish, or yellowish white: its lustre is shining and pearly; its fracture is radiated; it is hard, so as to scratch glass; is brittle, and harsh to the touch. Glassy Tremolite occurs massive, or crystallized in slender prisms aggregated: it differs from the others in its vitreous lustre. All these varieties are often phosphorescent, so that a moderate heat, or slight friction, produces a luminous appearance. Their chemical composition is extremely variable. Common Tremolite contains silex from 27 to 50, magnesia from 12 to 25, lime from 16 to 21, with small portions of alumina, carbonic acid, water, and iron.

BORACITE is a pure bi-borate of magnesia, consisting of magnesia 30.3, and boracic acid, 69.7. It occurs crystallized in cubes, of a white colour, with shining lustre, semi-transparent, and so hard as to scratch glass. They



become electric from heat, and before the flame of the blowpipe fuse into an enamel.

SULPHATE OF MAGNESIA occurs as an efflorescence, which appears to be formed by the action of air and humidity on sulphur and magnesia, existing in the earthy matter on which it is formed. It is distinguished by its bitter taste, and its chemical characters.

#### SECT. V.—*Of Argillaceous Minerals.*

THE Argillaceous Fossils afford a striking example of the variety of the external characters in species which belong to one genus; the gems distinguished by their transparency, lustre, and hardness, being comprised under them equally with the dull and plastic clays. They are connected entirely by their chemical relations.

The gems had been placed among the siliceous fossils, as allied with several of them in external characters, and silex had been supposed to be their principal ingredient. Bergman first shewed the error of this opinion, and proved by analysis, that in the emerald, sapphire, topaz, ruby, and hyacinth, argil predominates. The specific characters of these fossils had also been much perplexed by the distinctions of the jewellers, founded on those qualities which give them mercantile value, and particularly on colour, the most variable of all the external characters; and it has required much mineralogical discussion to establish the proper species. It now appears that the principal gems, which have been distinguished by the epithet of Oriental, the ruby, sapphire, and topaz, are varieties of one species. They have been ranked as such by Werner under the name of Sapphire, and by Haüy under that of Télésie; and Bournon, from their connection with the fossil named Corundum, has distinguished the species by



the name of Perfect Corundum. This arrangement has been confirmed by chemical analysis, the experiments of Klaproth, Vauquelin, and Chenevix, having proved that all of them consist of alumina nearly pure.

PERFECT CORUNDUM, the Sapphire of Werner, occurs in fragments, and crystallized; the forms of its crystals being the double three-sided pyramid, the single six-sided pyramid, and the six-sided prism, modified by truncations and acuminations. Its colours are blue, green, red, yellow, and yellowish-white, of numerous shades. It is transparent: its lustre is highly resplendent and vitreous: the fracture is conchoidal, or imperfectly foliated: the hardness inferior to that of the diamond, but superior to that of other fossils, and not yielding to the file: the specific gravity is from 3.9 to 4.1. The distinctions from colour form the different gems. The red constitutes the oriental ruby; the blue, the sapphire; the yellow, the topaz; the purple, the amethyst; the green, the emerald; the yellowish-green, the chrysolite. It is only to be remarked, that there are gems to which several of these names are also given, which are distinguished by the epithet Occidental, which are altogether different.

These fossils are not fusible by the blowpipe, but are said to have been melted by the heat excited by oxygen gas directed on burning charcoal. They are generally phosphorescent from friction. The variety of a blue colour, the Oriental sapphire, analysed by Klaproth, was found to be composed of 98.5 of alumina, 1 of oxide of iron, and 0.5 of lime: it is argil, therefore, nearly pure. The ruby afforded to Chenevix, 90 of alumina, 7 of silex, and 1.2 of iron.

IMPERFECT CORUNDUM, or, as it is generally named, Corundum, is a fossil which has been long used in India, from its great hardness, for polishing hard stones. It oc-



curs massive, and in crystals of the same forms as those of the perfect corundum. Its colour is greenish-white; externally it is dull, internally shining and vitreous: the fracture is foliated; it is very hard, but less so than the perfect corundum; its specific gravity is 3.7. From the aggregation of this fossil, it is scarcely acted on by any chemical agent, and from this Klaproth at one time supposed it to be composed of a new earth; subsequent investigation proved that it consists chiefly of alumina, the proportions being from 84 to 90, with 5 of silex, and from 1 to 7 of oxide of iron.

The fossil known by the name of Emery is of the same family. It occurs massive, or disseminated; is of a grey colour, dull and opaque. Its fracture is fine grained; it is nearly as hard as corundum, and is used like it for polishing the metals. According to Tennant, it is composed of 86.5 of alumina, 3 of silex, and 4 of iron.

To a species, distinguished by the name of Spinelle, are referred the gems known by the name of Spinell, and Balass Ruby. It occurs in grains, and octohedral crystals. Its colour is red, a deep crimson-red forming the spinell ruby; a pale rose red the balass ruby; its lustre resplendent: it varies from translucent to transparent: its fracture is conchoidal: it is very hard. According to Klaproth, it consists of 74.5 of alumina, 15.5 of silex, 3.25 of magnesia, 1.5 oxide of iron, and 0.75 lime. Vauquelin discovered 6.18 *per cent.* of chromic acid in it. The Ceylanite or Pleonaste of Haüy appears to be a variety of spinell.

The Occidental Topaz, which is found principally in Saxony, Siberia, and Brazil, deviates still more in composition from the corundum. It occurs in fragments, more frequently crystallized; in the oblique tetraedral prisms, variously modified. Its principal colour is yel-



low : its lustre is resplendent : it is very hard : its specific gravity is 3.5. The Saxon Topaz was found by Vauquelin to consist of 68 of alumina, 31 of silex ; but, by a subsequent analysis, he discovered fluoric acid in it, as well as in the Brazilian topaz. Berzelius has lately found the composition of the topaz to be 57.45 of alumina, 34.24 of silica, and 7.76 of fluoric acid. When white, the topaz is liable in small crystals to be mistaken for quartz, but may be distinguished by its surface being longitudinally streaked, while the crystals of quartz are streaked transversely.

SCHORLITE is allied in characters, and still more in composition, with Topaz. It occurs massive, or crystallized in long hexaedral prisms, having a shining lustre, of a light-yellow colour, sometimes green, or greenish-white ; its cross fracture is foliated ; it is moderately hard. It consists, according to Vauquelin, of 60 of alumina, 30 of silex, 6 of fluoric acid, and 2 of lime. PYROPHYSALITE is another variety. It occurs massive, of similar characters, and its composition is the same as that of the topaz.

CHRYSOBERYL occurs in grains, and crystallized under the forms of the six-sided table, and the double six-sided pyramid. Its colour is pale-green, often exhibiting a milk-white opalescence : its internal lustre is resplendent : it is semi-transparent : its fracture is conchoidal : it is so hard as to scratch glass. Arfwedson found it to consist of 81 alumina, and 18 silex, with a trace of iron. Seybert, however, has found in some Chrysoberyls from Connecticut, 17 *per cent.* of glucine, and a little oxide of titanium.

CYANITE has been placed under the magnesian genus, but it properly belongs to the argillaceous. It occurs massive, disseminated, and crystallized ; the crystals being oblique flat tetraedral prisms truncated on the lateral edges. Its principal colour is blue ; its lustre shining and



pearly: it is translucent, or transparent. Its fracture is radiated, or foliated. It consists, according to Klaproth, of alumina 55, silex 43, oxide of iron 0.5.

LEPIDOLITE occurs massive; the mass is of a purple colour, but presents white scales, of a pearly lustre: it is translucent on the edges: its fracture is small grained uneven; it is soft. It melts before the blowpipe, with intumescence, into a pearl-like matter. Gmelin has found it to consist of silex 52.2, alumina 28.3, oxide of manganese 3.6, potash 6.9, lithia 4.8, fluoric acid 3.6.

MICA is an important fossil, from its extensive distribution, as an ingredient in granite, mica slate, and other aggregate rocks. It occurs disseminated, in thin plates, and sometimes crystallized, in six-sided tables, and six-sided prisms; its usual colour is grey; the lustre of its plates is resplendent, and metallic; in thin plates it is transparent; its fracture is foliated, and it is very easily split into laminæ, which are flexible and elastic; it is soft, and feels smooth, but not unctuous. According to Rose, it consists of silex 46.3, alumina 36.8, oxide of iron 4.5, potash 9.2, fluoric acid 1.8. Peschier states, that he has found from 13 to 25 *per cent.* of oxide of titanium in mica. Pinite, though it has been considered a different mineral, agrees almost exactly in composition with mica, only wanting the fluoric acid.

HORNBLLENDE occurs massive, disseminated, and crystallized in prisms, usually aggregated. Its colour is black, with a tinge of green; its lustre is shining; when of a black colour it is opaque; when green, translucent on the edges. Its fracture is foliated, or broad radiated; it is scratched by the knife; but it cannot be broken but with difficulty. Before the blowpipe, it melts into a greyish-black glass. Its composition, according to Klaproth, is silex 42, alumina 12, lime 11, magnesia 2, oxide of iron



30. Basaltic Hornblende occurs imbedded in crystals usually small; their colour black; their surface smooth; their lustre splendid. Hornblende Slate is distinguished by its slaty fracture; it occurs massive, and often in large beds.

BASALT forms a mountain-rock, assuming often a columnar form. Its colour is greyish-black, with little lustre; it is opaque; its fracture usually uneven; it is scratched by the knife with some difficulty, and it is not easily frangible. It melts before the blowpipe into an opaque black glass; and from its fusibility has been employed in the manufacture of the coarser kinds of glass. According to Dr Kennedy, it is composed of silex 48, alumina 16, oxide of iron 16, lime 9, soda 4, muriatic acid 1, water and volatile matter 5.

CLINKSTONE has its name from the peculiar sound it gives when struck. It occurs as a rock, forming beds; its colour is grey; it is dull; its fracture is slaty. According to Klaproth, it is composed of silex 57.25, alumina 23.5, oxide of iron 2.25, manganese 0.25, soda 8.10, and water 3.

WACKÉ is an intermediate substance between basalt and clay. Its colour is greenish-grey; it is dull and opaque; it is soft, easily broken, and falls into pieces from exposure to the air. It occurs in large beds connected with basalt, clinkstone, and other trap rocks.

CLAY SLATE, or ARGILLACEOUS SLATE, forms extensive strata in connection with other primitive rocks, and likewise with those of transition. Its colour is grey, with shades of blue, purple, and green; its lustre is weakly shining; it is opaque; its fracture is slaty, or foliated; its specific gravity is from 2.6 to 2.8. Its composition, as found by Kirwan, is silex 38, alumina 26, magnesia 8, lime 14, oxide of iron 14. In some varieties potash has been discovered. Other kinds of slate have been dis-



tinguished, which however pass into each other, and the limits of the divisions cannot always be accurately marked. Whet-slate, or Hone-stone, is distinguished by its fracture, which is splintery, or scaly. Drawing-Slate is of a greyish-black colour, dull, and soft, so that it soils, and can be written with. Alum Slate is distinguished by affording alum from exposure to the air. Bituminous Shale is of a brownish-black colour; is very soft; laid on burning fuel, it gives a weak flame and a black smoke, and appears to consist of clay with bitumen. Slate Clay forms the transition into common clay; its fracture is slaty, approaching to earthy; it is soft, feels meagre, and adheres to the tongue; it softens and breaks down in water.

The term Clay is ambiguous, but is applied to those earthy mixtures, more or less indurated, which imbibe water, and may be kneaded into a paste somewhat ductile. Alumina is the base of all of them, and gives this predominating character; it is mixed with various proportions of silex, magnesia, lime, and oxide of iron. Indurated Clay, or Clay-stone, is clay in the highest state of induration. Its fracture is earthy, passing into slaty; it is soft, but is not easily diffused in water, and does not form with it a ductile paste. The purest Clay is that named Porcelain Clay, from the use to which it is applied; it is earthy; its colour white, with shades of grey, yellow, and red; it is dull and opaque; feels soft; in water it falls to powder, and when kneaded forms a ductile paste. It is, in general, infusible by any heat that can be raised. It consists essentially of silex and argil; but the proportions of these vary considerably. Mr Wedgwood found the porcelain clay of Cornwall to be composed of 60 of alumina, with 20 of silex; in others the silex is in larger proportion. Potter's clay and pipe clay are similar, but



less pure, generally of a yellowish or greyish colour from the presence of iron. Loam is the same substance, mixed with sand, oxide of iron, and various other foreign substances. The Boles, which are of a red or yellow colour, are of similar composition, and appear to owe their colours to oxide of iron. They are distinguished by their conchoidal fracture. The Ochres are similar to the boles, containing only more oxide of iron. Lithomarge is distinguished by its greater fineness, being composed of scaly particles, with a surface more or less smooth and shining; it is soft, feels greasy, and adheres to the tongue. Fuller's Earth has an earthy fracture, sometimes slaty, dull, opaque and soft. In water, it falls to powder, without forming a ductile paste: it is used to remove grease from cloth. Tripoli is found loose or indurated; its fracture is earthy; it feels harsh and dry; does not adhere to the tongue, nor soil; it moulders in water, but does not form a ductile paste. It is used for polishing the metals and glass.

The fossils named Diaspore, Gibbsite, and Allophane, are hydrates of alumina. Calaité or Mineral Turquoise is a hydrate of alumina, tinged of a rich blue colour by oxide of copper.

WAVELLITE occurs in fine capillary crystals, or in mammillary protuberances, having a radiated structure, white or greenish, semi-transparent, and of a pearly lustre. With respect to its composition, it is remarkable for the important error which has been successively made in its analysis, by three distinguished chemists, Klaproth, Sir H. Davy, and Mr Gregor. They each made the singular mistake of altogether overlooking not less than 35 *per cent.* of phosphoric acid which exists in it, and stated it to be merely a hydrate of alumina. Mr Gregor, indeed, suspected the presence of an acid in it, and fluoric acid



being afterwards found in some specimens, it was regarded as a sub-fluate of alumina. It is now known to be a hydrated phosphate of alumina.

CRYOLITE is a very rare fossil found in Greenland, which, from its composition, might be regarded as of a saline nature. It consists of alumina with soda, combined with a large quantity of fluoric acid. It has, however, no solubility in water, and is quite insipid. It occurs massive, of a white colour, and translucent: its fracture is foliated; it is soft and brittle; its specific gravity is 2.9. It melts before the blowpipe with the greatest facility, and then hardens. It dissolves in sulphuric acid, fluoric acid gas being disengaged. Sodalite occurs with it, which consists of alumina and soda alone.

NATIVE ALUM, a saline product, is to be regarded as belonging to the argillaceous genus, argil being its base, united with potash and sulphuric acid. It occurs generally as an efflorescence, either in the state of a powder, or in slender silky crystals, and possessed of all the properties of the artificial salt. ALUMINITE, or Sub-sulphate of Alumina, occurs near Brighton in white reniform masses, earthy, light, and soft; it consists of one equivalent of sulphuric acid, 3 of alumina, and 9 of water.

#### SECT. VI.—*Of Glucine Minerals.*

IN the fossils which may be placed under this genus, silex is the earth present in largest quantity, but glucine is the one which gives the predominating character, as is well displayed in the interesting fact which led to the discovery of this earth, that in the Beryl and the Emerald, the two principal fossils belonging to it, the primitive form of the crystals is the same.



THE OCCIDENTAL EMERALD is that to which the name of Emerald is properly applied. It occurs crystallized, in short six-sided equiangular prisms, perfect or truncated on the edges, or angles. Its colour is that pure and rich green, which has derived from it the name of emerald green; its lustre is resplendent and vitreous; it varies from translucent to transparent; its fracture is small conchoidal; it is hard, but less so than the preceding gems. It is melted with difficulty by the blowpipe into a white glass. It consists, according to Vauquelin, of silex 64.5, argil 16, glucine 13, and green oxide of chrome 3.25. BERYL is so analogous in properties and composition to the emerald, that it may be doubted if they are not varieties of the same species, chrome only being wanting, to which is to be ascribed the absence of the rich green colour of the emerald: according to Berzelius, it contains 0.3 *per cent.* of oxide of columbium. Its colour is pale green, which passes into blue or yellow; it occurs in larger crystals than the emerald.

Euclase is of somewhat similar composition, consisting, according to Berzelius, of silex 43, alumina, 30, glucine 21.7. It occurs crystallized, of a green colour; its lustre resplendent and vitreous; it is transparent; the fracture is foliated; it is hard and brittle.

#### SECT. VII.—*Of Siliceous Minerals.*

THE siliceous fossils can scarcely be distinguished by any common characters, but are connected in a great measure from their chemical relations.

QUARTZ may be placed at the head of the genus, as consisting almost entirely of silex. Analysed by Bergman, it was found to be composed of 93 of silex, 6 of argil, and



1 of oxide of iron. When perfectly transparent, it is named Rock Crystal. It occurs crystallized usually in six-sided prisms, acuminated at both extremities by six planes, set on the lateral planes; sometimes the prism is wanting, or nearly so, and then the form is the double six-sided pyramid, and frequently the single six-sided pyramid only is apparent. It occurs also massive and disseminated. Its most frequent colour is white; sometimes it is brown, and more rarely yellow and red. Its lustre is highly vitreous; it is transparent, or semi-transparent. Its fracture is splintery, or conchoidal: it is hard, so as to give sparks with steel; its specific gravity is 2.6. It is infusible before the blowpipe, and is imperfectly softened by the heat excited by a stream of oxygen gas. It is a fossil extremely abundant, and of extensive distribution.

When of a purple colour, it has received the name of AMETHYST: this colour, it is found, is owing to the presence of the intermediate red oxide of manganese. ROSE QUARTZ, or Milk Quartz as it has been named, usually of a rose-red colour, sometimes milk-white, is another variety; as is the fossil named PRAISE, distinguished by its leek-green colour.

CHRYSTOPRAISE is a pure siliceous fossil, coloured by a little oxide of nickel. Its colour is apple-green; it has little lustre; is translucent; its fracture is even. Before the blowpipe it loses its colour, but does not melt.

OPAL is a pure hydrate of silica. The Noble or Perfect Opal consists of 90 of silex, with 10 of water; the common opal, of 94.5 of silex, 5 of water, and one of oxide of iron. The perfect opal is distinguished by the beautiful play of colours which it exhibits, green, red, blue, and yellow, of numerous shades, varied according to the position. Its proper colour is milk-white; its lustre is splendid and vitreous; it is translucent; its fracture



is conchoidal. The common opal has the same characters, but does not present the variegated effulgence of colours of the precious opal. The semi-opal has less lustre and transparency, is more dense, hard, and heavy, and contains a large portion of oxide of iron. Some varieties of opal, which appear to have lost the water they contain from exposure to the air, and in consequence have become opaque, recover their transparency when immersed in water. These have been named *Hydrophanes*. *Hyalite* seems to be a variety of the common opal. It occurs disseminated of a white colour and glassy lustre. *Menelite*, according to Klaproth, is of the same composition. It occurs in tuberosse masses imbedded in adhesive slate. The fossil named *Cat's Eye*, from its property of reflecting in certain directions a changeable whitish effulgence similar to the eye of a cat, appears to belong to the same family.

*CHALCEDONY* is a species also composed almost entirely of *silex*. It occurs massive, frequently in nodules, botryoidal, stalactitic, and in other imitative shapes, sometimes in veins. Its colours are white, with shades of blue, grey, and yellow; and these are often arranged in stripes parallel or concentric; it has not much lustre, but is susceptible of a fine polish, from which lustre is acquired; it is translucent; its fracture is even; it is hard, so as to strike sparks with steel. *CARNELIAN* is a variety distinguished principally by its red colour and conchoidal fracture. *Cacholong* is chalcedony of a milk-white colour. *Onyx* is that variety in which stripes of different colours alternate. Chalcedony stained with dark coloured spots, veins, or arborizations, forms the *Mocho stone*. To this species may also be referred the greater number of *AGATES*, as chalcedony is generally their basis, their being intermixed with it jasper, quartz, flint, or other siliceous fossils, forming a blended mass.



FLINT is a very pure siliceous fossil; the silex in its composition amounting to 98 in 100 parts, with traces of alumina, lime, and oxide of iron. It occurs in nodules, imbedded in chalk or limestone: its colour is grey, passing into yellow, brown, or black; its lustre is weakly shining; its fracture is perfectly conchoidal; its fragments sharp-edged; its hardness such, that it gives copious sparks with steel. It is phosphorescent from friction. Flinty Slate, or Siliceous Schistus, resembles flint, differing in its slaty fracture. The Lydian Stone is another variety, having an even fracture, darker colour, and less hard than flint.

HORNSTONE, or PETROSILEX, is allied to these. Its colour is grey; it is translucent on the edges; its fracture is splintery, or conchoidal; its fragments are sharp-edged. Like the preceding fossils, it is infusible before the blow-pipe, and, according to Kirwan, contains more alumina. Under this species is placed the siliceous petrified wood, or Woodstone, this being composed of siliceous matter analogous to hornstone, introduced by slow infiltration, into the substance of wood, while the vegetable matter, by slow decomposition, has been removed. It retains the appearance of the ligneous texture, and often its organic form.

JASPER.—In this fossil the proportion of alumina to silex is increased, and in some varieties so much that there is a transition to indurated clay; it also contains oxide of iron. Its most common colours are red, yellow, and brown; it is opaque, and has little lustre; it is, however, susceptible of a fine polish; its fracture is more or less conchoidal; it is less hard than flint, but still is not scratched by the knife. Ribband Jasper, or Striped Jasper, is distinguished by its colours being arranged in stripes generally straight. The Egyptian Jasper which



occurs in nodules, and exhibits various shades of colour, generally brown, in concentric stripes, is another variety. Heliotrope, or Bloodstone, has been considered to differ little from jasper; it is, however, a much purer siliceous mineral, consisting, according to Brandes, of silex 96, oxide of iron 1.25, a little alumina and water. Its colour is green, generally marked with crimson-red spots.

PITCHSTONE has received its name from the resemblance in lustre and texture which it has to pitch. Its colours are green, brown, red, and black; its lustre resinous; its fracture is conchoidal; it is moderately hard, and very brittle. It is fusible before the blowpipe, by which it is distinguished from any varieties either of opal or jasper. Its analysis by Klaproth gave 73 of silex, 14.5 of argil, 1 of oxide of iron, 1.75 of soda, and 8.5 of water. From pitchstone there is a transition to what has been called Pearlstone, and from that to Pumice, both of which occur vesicular, have a pearly lustre, are brittle and light, and similar in composition. Obsidian is related to them. It is of a deep black colour; its lustre is highly splendid and vitreous; its fracture is large conchoidal; its fragments sharp-edged. It melts before the blowpipe into an opaque spongy glass. It is composed of 69 of silex, 22 of alumina, and 9 of oxide of iron: it often contains 9 or 10 *per cent.* of water. Potash and soda have also been found in it in small quantity.

FELDSPAR is an important fossil, from its extensive distribution, as a component part of several aggregate rocks; indeed, next to quartz and oxide of iron, it is the most abundant of minerals. Foliated or Common Feldspar occurs massive, disseminated, and often crystallized, in prisms of four or six sides, variously modified. Its colours are principally red, white, and grey; its lustre is shining, and intermediate between vitreous and pearly,



and is varied according to the position with regard to incident light; its fracture is foliated, and its fragments rhomboidal. It is moderately hard, so as to scratch glass. It melts before the blowpipe into a white glass. Its chief ingredients are silex 66, alumina 17, and potash 12. Considering the silex as an acid, Feldspar consists of trisilicates of alumina and potash, with a little lime and iron. Some varieties of feldspar are decomposed by exposure to the air, become earthy, and pass into clay; a change probably produced by the removal of some of their principles, perhaps of the potash, by the infiltration of water.

Foliated Feldspar enters into the composition of many of the aggregate rocks, and in those of every formation. Granite consists of it, intermixed with quartz and mica, and the feldspar almost always forms the principal part or basis of the granite. Gneiss is the same aggregate, having a slaty texture; and Siennite is characterised by the addition of hornblende to the other ingredients. Greenstone is an aggregate of feldspar and hornblende: and the chief varieties of Porphyry are those where grains or crystals of feldspar are imbedded in a base of hornstone, pitchstone, or indurated clay.

ADULARIA is a variety of foliated feldspar, distinguished by its greater lustre, which is pearly, and reflected from the internal plates, and by greater transparency, and hardness. The Moonstone, as it has been named, is a variety of Adularia. Labradore Feldspar is distinguished by the property of reflecting in certain positions, as the light falls upon it, beautiful colours, particularly blue, green, and red; a property probably arising from decomposition, and the consequent alteration of its lammellæ. Glassy Feldspar occurs in porphyry slate, crystallized in six-sided tables, and four-sided prisms of a grey colour. Sommite or Nepheline is a variety of it: it consists of si-



lex 44, alumina 33, and soda 20. It occurs in six-sided prisms, which scratch glass.

Albite or Cleavelandite is a variety of Feldspar, which has been only lately distinguished. It contains nearly the same proportions of silex and alumina, but instead of 16 *per cent.* of potash, contains 9 *per cent.* of soda. Its characters are similar to those of Feldspar, but its colour is paler, frequently greenish white.

Compact Feldspar is a variety, which has much less lustre and transparency; its fracture is splintery, or fine grained; and its fragments are not rhomboidal; its hardness is also inferior. It forms a mountain rock, and is often an ingredient in aggregate rocks. It passes into what has been named Petrosilex or Hornstone, but is distinguished by its fusibility before the blowpipe. The fossil named Saussurite, from the elder Saussure who discovered it, approaches closely to compact feldspar, differing chiefly in containing a larger proportion of iron.

JADE, the NEPHRITIC STONE of mineralogists, appears to approach to compact feldspar. It had been classed among the magnesian fossils; but analysis has shewn that it contains no magnesia; its composition being silex 53.75, lime 12.75, alumina 1.5, oxide of iron 5, oxide of manganese 2, soda 10.75, potash 8.5, water 2.25. It occurs in rounded masses; its colour is leek-green, which passes into light yellow; it is dull; it is hard and difficult to break; is slightly unctuous to the touch. Before the blowpipe it melts into a white semi-transparent glass. BILDSTEIN, and the Agalmatholite or figure stone of the Chinese, appear to belong to the same species; their characters are not very dissimilar, and they are of nearly the same composition. The Axe-stone, which has derived its name from being used by the natives of the South Sea in making hatchets, is also a variety of the Bildstein.



Tabular Spar consists of two atoms of silica and one of lime. It is of a yellowish colour, with a shining and pearly lustre.

Andaluzite, or Hard Spar, is allied in characters to feldspar, but is distinguished by greater density and hardness, and its infusibility before the blowpipe. It occurs in connection with quartz and mica, crystallized in rectangular four-sided prisms; it is of a flesh-red colour, translucent, and extremely hard.

SPÖDUMENE, or TRIPHANE, contains a considerable proportion of lithina. It occurs massive, of a foliated fracture, with a shining pearly lustre; translucent, hard, and easily frangible, breaking into rhomboidal fragments. Before the flame of the blowpipe it divides into yellow scales, and then melts into a greenish glass. Petalite is similar in characters and composition.

SCAPOLITE is closely allied to Feldspar. It occurs massive and crystallized, and is distinguished into sub-species, according as its fracture is foliated, radiated, or compact. Regarding silica as an acid, scapolite consists of 3 particles of silicate of alumina united to 1 particle of silicate of lime. Meionite, which was before regarded as a variety of glassy feldspar, differs from scapolite, only in containing 2 particles of silicate of alumina instead of 3. ELAOLITE or FETTSTEIN differs from Scapolite, in containing not less than from 16 to 18 *per cent.* of potash.

ZEOLITE was originally distinguished as a species by two chemical characters, that of fusing with intumescence before the blowpipe into a white spongy glass, and dissolving in acids, the solution being gelatinous. But it occurs under different forms, forming sub-species well defined, and the characters of some of which differ so much that they form perhaps even species. The common Fibrous Zeolite occurs massive; its fracture is distinctly fibrous, scopiform,



or stellular divergent; it is usually white with a pearly lustre, faintly translucent; is semi-hard, brittle, and its specific gravity does not exceed 2.2. Needle Zeolite occurs massive, and also in acicular prisms; the fracture is radiated, the lustre shining and vitreous; the crystals are transparent or semi-transparent; they are semi-hard and brittle. These constitute the Mesotype of Häuy. Mealy zeolite is an earthy variety, occurring in soft friable masses. Laumonite also exhibits the characters of Mesotype, in forming a gelatinous solution with acids; it is of a white colour and pearly lustre, very liable to disintegration from exposure to the air. The Stilbite of Häuy, including the radiated and foliated zeolites, differs from Mesotype in not forming a jelly with acids. Radiated Zeolite occurs massive, and in rectangular four-sided prisms; the fracture is radiated; the lustre shining and pearly; the colour usually white. Foliated Zeolite occurs massive, and in broad prisms and tables; the fracture is foliated, the lustre shining and vitreous. Heulandite is the same mineral, differing merely in crystalline form. All these sub-species agree nearly in chemical composition; they appear to consist essentially of silex and alumina, with a smaller proportion of lime, and a considerable quantity of water. When the Mesotype and Laumonite are acted on by the acids, the soluble earths are dissolved, while the silex, in minute particles, and probably in combination with water, being diffused through the liquid, gives the gelatinous consistence. The intumescence before the blowpipe is probably owing to the expulsion of water from the fused matter.—APOPHYLLITE, or Fish-eye Stone, is allied to the zeolites in chemical characters and external appearance. It is distinguished by a slight iridescence in its fracture surface, and by the facility with which it



exfoliates when heated. In composition it differs in containing less alumina and more lime.

CUBIZITE, or ANALCIME, occurs in cubes perfect or acuminate on each angle by three planes. Its colour is white; its lustre vitreous; is harder than zeolite, so that it scratches glass; it is also heavier, and does not form a jelly with acids. It consists of silex 58, argil 18, water 8, soda 16. CHABASITE occurs in small white crystals, oblique rhombs usually super-imposed. It contains 10 *per cent.* of soda.

PHRENITE approaches in characters to zeolite, but is harder and heavier, and does not form a jelly with acids. It occurs massive, and crystallized in quadrangular prisms, and oblique four-sided or six-sided tables, often aggregated. Its colour is green; its fracture foliated or radiated; it scratches glass.

NATROLITE belongs to this family. It occurs massive, and in its fracture presents straight or diverging fibres; its colour is light yellow. It fuses readily before the blowpipe, and contains not less than 16 of soda in 100 parts, combined with silex and argil.

LAZULITE, Lapis Lazuli, or Azure Stone, is of a rich azure-blue colour; with little lustre; its fracture is uneven; it is so hard as to scratch glass. It melts before the blowpipe into a white enamel, and if previously calcined, is soluble in acids, forming a jelly. Klaproth found it to be composed of 46 silex, 14.5 argil, 28 carbonate of lime, 6.5 sulphate of lime, 3 oxide of iron, and 2 water. It is used in Mosaic work, and its powder affords the paint known by the name of Ultramarine, which in beauty and durability of colour exceeds all known pigments. It is an inquiry of some interest to determine what this intense blue colour is owing to; and as ultramarine is extremely high priced, being prepared only from the Lapis



Lazuli, it would be a valuable discovery if it could be artificially formed. Though both the pigment and the mineral have been carefully analysed, it is a singular fact, that no substance has yet been discovered in either capable of communicating any colour, far less the rich blue which they exhibit. At one time it was supposed that copper existed in ultramarine, but this was disproved by the analysis of Klaproth. As in that analysis 3 *per cent.* of iron were found to be present in it, the colour was next attributed to that metal, but neither of the oxides of the iron can give a blue colour; and if they did, so small a proportion could not be productive of so bright a colour throughout the whole mass. But, farther, Clement and Desormes have proved, that Ultramarine and Lapis Lazuli, free from pyrites, contain no iron, nor any metallic oxide, the former consisting of silica 35.8, alumina 34.8, soda 23.2, sulphur 3, carbonate of lime 3; and this statement has been confirmed by Mr Phillips. As almost every coloured mineral derives its tint from some metallic oxide, Lapis Lazuli thus presents a striking anomaly. The changes which it suffers are also unfavourable to the existence of any metallic colouring matter, for its colour is destroyed by acids, and yet, on neutralizing the acid by an alkali, the colour does not re-appear; the colour also is in no degree affected by sulphuretted hydrogen, a circumstance which constitutes, indeed, one of the chief recommendations of the pigment. Instead of fading like most other paints, ultramarine is said also to become brighter by age. M. Thenard remarks, that it is possible that these colourless ingredients may, by combination, form a coloured compound, a supposition, however, of little probability. Mr Phillips rather inclines to the opinion, that the colour of Ultramarine and Lapis Lazuli is owing to some peculiar non-metallic substance



yet undiscovered. AZURITE differs from lazulite in being of a foliated fracture, softer and a deeper blue. Before the blowpipe it loses its colour, but does not melt: it has been stated to consist chiefly of phosphate of alumina. HAÜNE is of a deep sky blue colour, semi-transparent, with a vitreous lustre. Before the blowpipe it melts with difficulty, retaining its colour; it forms a jelly with acids. It consists chiefly of silex and alumina, with sulphate of lime 21.7, potash 15.5, oxide of iron 1.2, sulphuretted hydrogen 3.4. BLUE SPAR is of a pale smalt blue, with little lustre; its fracture is imperfectly foliated; it loses its colour before the blowpipe.

STAUROLITE, or Cross Stone, derives its name from frequently occurring in twin crystals, (rectangular four-sided prisms acuminate by four planes,) which intersect each other, so that the double crystal has the appearance of a cross. Its colour is white; its lustre shining and vitreous; its fracture is foliated; it is hard; it melts before the blowpipe, and is phosphorescent when thrown on burning fuel. It consists of 49 of silex, 16 of argil, 18 of barytes, and 15 of water.

GARNET occurs usually crystallized in dodecahedrons, with rhomboidal faces, either perfect, or truncated on the edges, giving 36 faces. The variety named the precious garnet is almost always crystallized; the common is often massive. The former is of a red colour, with a vitreous lustre, and sometimes completely transparent; its fracture is conchoidal; it is harder than quartz; its specific gravity is from 4 to 4.3: it is therefore one of the heaviest of the earthy fossils. The common garnet has less lustre and transparency, and its colours are deeper; it is less hard and heavy. Both varieties are melted before the blowpipe. They consist of silex and argil, with a large proportion of oxide of iron. Pyrope, or Bohemian Gar-



net, is distinguished from the precious and common garnet, by its being perfectly transparent, of a blood-red colour; and it occurs not crystallized, but in imbedded grains: it contains less oxide of iron, and 10 *per cent.* of magnesia. MELANITE, or Black Garnet, as it is named from its deep black colour, occurs crystallized in six-sided prisms truncated at the edges, and acuminate by three planes, with a shining lustre, opaque and heavy. CINNAMONSTONE may be regarded as a variety of garnet; it occurs in fragments of a yellowish-brown colour, having a resinous lustre, translucent, hard, and with an imperfect conchoidal fracture.

GRENATITE, the Staurotide of Haiiy, occurs crystallized in the form of a broad six-sided prism, of a reddish colour, opaque, hard and brittle: the crystals are often double, one intersecting another in the form of a cross.

LEUCITE, a fossil which occurs imbedded in lava, was, from the appearance of its crystallization, named White Garnet; but it differs altogether in its characters. Its colour is white, with a yellowish or greyish tinge; its internal lustre vitreous; its fracture is foliated; its specific gravity is 2.4. It is not fused before the blowpipe. It consists of silex 56, argil 23, and potash 21; from the quantity of alkali it contains, if it is reduced to powder, and thrown into a blue vegetable infusion, it turns it to green.

VESUVIAN is crystallized in rectangular four-sided prisms, truncated on the edges. Its colour is olive-green, passing into yellow, or brown; its external lustre is splendid and vitreous; it is translucent; it is harder than quartz. It melts before the blowpipe into a yellowish glass.

OLIVIN occurs in grains or rounded pieces, or crystallized in four-sided prisms. Its colour is green; its lustre



vitreous ; its fracture is small conchoidal. It consists of silex from 40 to 50, of magnesia from 37 to 38, lime 20.5, oxide of iron 12.5. With this fossil the **CHRYSO-LITE** has been united by Haüy ; in composition and characters they are nearly the same. **AUGITE** has also considerable resemblance to olivin, and is frequently found with it. It differs in the form of its crystals, which is a rectangular six-sided prism bevelled on the extremities ; its colour is a darker green, approaching to black ; it is harder and heavier. Professor Mitscherlich has lately, it is said, succeeded in forming artificial crystals similar to those of Augite, by mixing quantities of its ingredients in the proportion in which they exist in it, and heating the mixture strongly in a porcelain furnace. **COCCOLITE** and **SAHLITE** are varieties of the same species. The former occurs massive, in granular distinct concretions, of a green colour with considerable lustre. The latter occurs massive and crystallized in prisms of a green colour with considerable lustre and transparency ; it is brittle and fusible before the blowpipe.

**THUMERSTONE**, or **VIOLET SCHORL**, occurs crystallized in very flat rhombs. Its colour is clove brown which passes into violet, or into grey ; its external lustre is splendid ; it is nearly of the hardness of quartz. It melts before the blowpipe into a greenish glass. It consists of 44 silex, 18 argil, 19 lime, 14 oxide of iron, 4 oxide of manganese.

**SCHORL** is of a black colour, with a lustre weakly shining ; is generally opaque, or slightly translucent on the edges. It occurs massive, and frequently crystallized in prisms ; its fracture is imperfectly conchoidal ; its hardness a little inferior to that of quartz. It melts with ebullition before the blowpipe into a greyish slag. It is distinguished by becoming electric by heat, presenting at



one extremity positive electricity, at the other negative. The Tourmalin is very nearly allied to schorl, and is chiefly distinguished from it by its colours, which are brown, green, red, and blue, of numerous shades, generally dark, and by its greater lustre. Rubellite and Indicolite are red and blue tourmalins. Lithina, boracic acid and soda are sometimes discovered in tourmalin.

PISTACITE, Epidote, or Thallite, has been ranked as a variety of actynolite; but in composition it approaches to the tourmalin. It is usually crystallized in six-sided, or oblique four-sided prisms; is of a pistachio-green colour; the lustre is vitreous; the fracture foliated or radiated.

LIEVRITE or YENITE, occurs massive and in prismatic crystals, of a brownish-black colour, with resinous lustre, and opaque; its fracture is uneven; it melts before the blowpipe into a greenish glass. According to Vauquelin, it consists of silica 28, lime 12, oxide of iron 55.

Besides these fossils, silex is found deposited in a stalactitic form, from waters in which it has been previously in a state of solution. The deposit from the Geyser fountain is the principal example of this kind. It occurs in massive white pieces; the surface sometimes botryoidal; its fracture is compact or fibrous; it has scarcely any lustre; it is usually friable, sometimes indurated. It consists, according to Klaproth, of 98 of silex, 1.5 of argil, 0.5 of oxide of iron. Similar deposits are formed from other mineral springs; in some siliceous stalactites, the surface is even covered with crystals of quartz.

#### SECT. VIII.—*Of Zircon Minerals.*

To the zircon genus of fossils belong two fossils, the Zircon or Hyacinth, and the Eudialite.



ZIRCON, or JARGON, occurs in angular grains, and crystallized, of a grey colour, with frequently shades of green, blue, yellow, and brown; its internal lustre is resplendent and adamantine; it is transparent; its fracture is small conchoidal; it is extremely hard, so as to be scarcely affected by the file; its specific gravity is 4.7. Dr Thomson supposes it to consist when pure of zircon 75, siliceous 25, oxide of iron 0.5. It is cut as a gem, and has some resemblance to the diamond in its play of colours. The HYACINTH differs from it chiefly in its colour, which is what has been named Hyacinth Red, owing probably to the presence of a larger portion of iron; its lustre is resinous; it is semi-transparent; its fracture foliated; it is very hard, scratching quartz. It loses its colour before the flame of the blowpipe, is not fused, but melts with borax into a transparent glass.

Eudalite is a very rare mineral, discovered by Sir Charles Giesecke, on the coast of Greenland, associated with sodalite. It occurs massive, or in octohedral crystals with truncated edges, of a hyacinth red colour, hard, and with a conchoidal fracture. Before the blowpipe, it melts easily into a green bead. Its ingredients are siliceous 53, yttria 11, soda 13, lime 9, oxides of iron and manganese, and muriatic acid.

#### SECT. IX.—*Yttrious Minerals.*

GADOLINITE forms the principal species of the genus of earthy fossils of which Yttria is the base. It occurs massive and disseminated; its colour is deep black; its internal lustre is resplendent; it is opaque, or feebly translucent; its fracture is conchoidal; its hardness is such that it is not scratched by the knife; its specific gravity is



4.2. It intumesces before the blowpipe, but is not fused. With nitric acid it forms a gelatinous solution. It consists, according to Berzelius, of silex 25.8, yttria 45, oxide of cerium 17.9, oxide of iron 11.4.

The Orthite, Ytthro-tantalite, and Ytthro-cerite also contain Yttria as an ingredient; but as in these the proportions of oxide of tantalum and oxide of cerium are larger, they may more properly be placed as metallic fossils.

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### CHAP. III.—OF METALLIC MINERALS.

UNDER this order are comprised those native combinations in which metals are alloyed with each other, or in which they are united with other substances, forming what are named Metallic Ores. The substances with which they are most generally combined are sulphur and oxygen, and in a few cases, chlorine, and several of the acids, particularly the carbonic, more rarely the sulphuric, and phosphoric. The individuals under each genus are connected entirely by their common relation to the metal which forms its base. Metallic minerals retain in general the characteristic metallic qualities, lustre, opacity, and great specific gravity, though to this there are exceptions.

#### SECT. I.—*Of Native Gold.*

NATIVE gold occurs pure, or alloyed with portions of other metals, more particularly with silver, copper and tellurium. Its colour is yellow: its lustre is metallic and shining; it is soft, highly malleable, and ductile; its frac-



ture is hackly; its specific gravity is always above 12, and rarely equal to 19. It occurs sometimes, though rarely, crystallized; the forms of the crystals being the cube, the octaedron, and the rhomboidal dodecaedron; it is also found capillary, and in thin plates or spangles; sometimes also in small grains in the sand of rivers and streams, forming what is named Gold Dust. Besides this variety of Native Gold, there is one of a brass-yellow colour, generally disseminated, or in small plates, in which the gold appears to be alloyed with silver and a little iron; and another of a steel-grey colour, passing to yellow, in which the proportion of alloy is greater.

Some minerals have been regarded as ores of gold, though they are not strictly so, as they contain larger quantities of other metals. The principal of these is the native alloy of tellurium, the Graphic Gold ore, which consists of from 20 to 27 of gold, with from 45 to 60 of tellurium, and 10 of silver. It is in minute crystals of a greyish-white colour, attached to each other laterally, and dispersed on the surface of the matrix, so as to bear some resemblance to printed letters, whence its name. Gold is also found in smaller quantity in some other ores, especially in some varieties of sulphuret of iron, or pyrites, which are hence named Auriferous.

## SECT. II.—Of Native Platina.

PLATINA, like gold, exists only in the metallic form, forming what is named Native Platina, found in South America. It is in the form of grains, but pieces have been met with of larger size. Its colour is a light steel-grey; its lustre metallic and shining. It is malleable, flexible, and has a specific gravity above 15. It is almost



infusible, and is soluble only in nitro-muriatic acid. More lately platina has been found associated with some silver ores, at Guadalcanal in Estremadura, without any of the foreign metals contained in the Platina of Peru.

### SECT. III.—*Of Ores of Silver.*

SILVER is found native, and mineralized. Native silver has the general qualities of the metal. Its colour is white, though frequently tarnished; its lustre metallic; it is perfectly malleable and ductile, usually flexible: it is soft; its fracture is hackly. It occurs branched, capillary, in thin plates, and in crystals generally small and aggregated.

By an alloy of antimony with silver, characters are acquired sufficiently distinctive to form a species, which has been named Antimonial Silver. It has less lustre; its colour is tin-white, its fracture is lamellated, and it is brittle. It consists of from 67 to 84 of silver, with from 24 to 16 of antimony. Another native alloy of silver is that named Arsenical Silver. Its colour is tin-white, tarnished; its fracture is foliated: it is soft and brittle. It occurs massive and crystallized, in six-sided prisms or pyramids. Before the blowpipe it exhales vapours of arsenic and antimony. It consists of 35 arsenic, 44 iron, 12 silver, and 7 of antimony.

The Vitreous Silver Ore, or Silver Glance, is a pure sulphuret of silver. Its colour is lead-grey; its lustre glistening, and metallic; it is soft, malleable, and flexible. It occurs of various imitative shapes, as filiform, and in minute crystals.

The Red Silver Ore consists of sulphuretted oxides of silver and antimony. Its colour is red, of various shades; its lustre is shining, and metallic or adamantine; when



crystallized it is semi-transparent; it is soft and brittle. It occurs disseminated, dendritic, and minutely crystallized. Heated on charcoal by the blowpipe, it decrepitates, melts, exhales a white vapour, and gives a globule of silver.

Grey Silver Ore can scarcely be strictly regarded as an ore of silver, since it contains not more than from 9 to 20 parts of silver in 100 parts, combined with from 40 to 48 of lead, from 8 to 21 of antimony, and from 12 to 22 of sulphur. There are two varieties of it, the light grey, or white silver ore, having a shining and metallic lustre; and the dark-grey silver ore, the colour of which is iron-grey, passing to black without lustre. They pass into each other, and into the other metallic sulphurets.

Silver mineralized by chlorine forms a well-defined species, Horn Silver Ore, as it has been named. Its colour is pearl-grey, passing into white or blue; its lustre is shining; it is translucent, gives a shining streak; is soft, so as to be easily cut, is also malleable. It occurs massive, more frequently crystallized; its crystals being acicular, or aggregated cubes. Heated by the blowpipe it melts, exhales a disagreeable odour, and gives a globule of silver. Another chemical character of it is, that when breathed on, and rubbed by a piece of iron or zinc, the rubbed surface exhibits a film of reduced silver. A silver ore from Mexico, analysed by Vauquelin, was found to contain 18.5 *per cent.* of iodine, along with lead and sulphur. This new ore was of a white colour, resembling native silver with a lamellated structure; the colour of its fracture surface was yellowish-green.

These are the proper silver ores. This metal is likewise present in small quantity in other metallic ores; from which, from its commercial value, it is an object to extract it; but these do not properly belong to this genus.



SECT. IV.—*Of Ores of Quicksilver.*

THIS metal occurs native and mineralized. Native Quicksilver is found in globules, on the surface, or in the crevices of other mercurial ores, or other fossils, retaining the lustre, opacity and mobility of the metal. Sometimes it has an alloy of silver, so as to give a soft, and even a firm consistence; and when the proportion of silver is large, it forms a species, which occurs crystallized.

Quicksilver combined with chlorine, and a portion of sulphuric acid, forms the species named Mercurial Horn Ore. This generally occurs in small grey crystals, having a pearly lustre. It is faintly translucent; its fracture is foliated; it is soft and brittle, so as to be easily scraped, or cut with a knife. Before the blowpipe it is volatilized.

Cinnabar, the most abundant ore of mercury, is a bisulphuret of this metal. Its colour is red, of various shades; its lustre varying from shining to dull. It occurs massive, disseminated, and in small crystals, which are translucent or semi-transparent; when massive, it is opaque. It is brittle and soft. Heated by the blowpipe, it is volatilized, with smoke, a blue flame, and an odour of sulphur.

Hepatic Quicksilver Ore occurs massive. Its colour is intermediate between dark-red and lead-grey; it is dull and opaque. Its fracture is even or slaty. It is soft and brittle. It is probably cinnabar, altered by intermixture.



SECT. V.—*Of Ores of Copper.*

COPPER occurs native, and likewise mineralized, forming several species of ores, in general well defined.

Native Copper like the metal is of a red colour, but frequently tarnished: its lustre is metallic; it is flexible, ductile, and malleable; its fracture is hackly. It occurs in branched pieces, dendritic, in thin plates, and indistinctly crystallized.

Red Copper Ore is the pure protoxide of copper. It occurs massive, in plates, disseminated, and crystallized. Its colour is cochineal-red; its lustre semi-metallic, or adamantine; it is opaque when massive; transparent, or semi-transparent, when crystallized; its specific gravity is about 3.9. Its fracture is compact, foliated, or fibrous, whence different varieties are formed. The brick red or tile copper ore, which occurs earthy or little indurated, appears to be a mixture of oxide of copper and oxide of iron.

Diopase, or Emerald copper, consists of an equivalent of peroxide of copper, three of silex, and two of water. It occurs crystallized in six-sided prisms, terminated by three-sided pyramids, of a rich green colour and foliated fracture.

Oxide of copper combined with carbonic acid forms two species, the Blue and the Green Carbonate; the differences between which arise either from different states of oxidation, or in part from the combination of water. The Blue Carbonate is named Mountain Blue, or Azure Copper Ore. One variety is earthy, usually an incrustation, sometimes massive, without lustre. Another variety is indurated: its principal colour is azure-blue: when crystallized, its lustre is shining; and it is translucent,



its crystals are four-sided prisms, acuminated by four planes; they are small and aggregated. This species dissolves in nitrous acid with effervescence. As analysed by Mr Phillips, it consists of 69 peroxide of copper, 25.4 carbonic acid, and 5.4 water.

The Green Carbonate comprises two varieties, Mountain Green and Malachite. The first is massive, but more generally occurs as an incrustation; its colour is verdigris-green, without lustre; its fracture earthy; it is soft and brittle; it effervesces, though slightly, with acids, and appears to consist of carbonate of copper, with argil and lime. The other variety, Malachite, occurs massive, disseminated, and crystallized in capillary and acicular prismatic crystals; its colour is green; its lustre silky and pearly; its fracture is striated, the striæ being usually divergent. It contains more oxygen and more water than the blue carbonate. Chrysocolla is a green carbonate, containing a large quantity of siliceous matter and water.

Copper mineralized by phosphoric acid forms a rare ore, formerly regarded as malachite, but now found to be a bi-phosphate of the peroxide. It occurs massive, disseminated, in cubic crystals small and grouped, of a green colour, often black on the surface, with vitreous lustre, and opaque: its fracture is fibrous.

Another rare species consists of the metal mineralized by muriatic acid, the green copper sand of Chili; it occurs in angular grains of a bright green colour. According to Dr Davy, it consists of peroxide of copper 73, muriatic acid 16.2, water 10.8, or it is a submuriate of copper. It dissolves in nitric and muriatic acids without effervescence, and heated with sulphuric acid exhales muriatic acid. A submuriate of nearly similar composition occurs in six and four-sided prismatic crystals, transparent, and with much lustre.



Sulphate of copper occurs in solution in the water of copper-mines : and is sometimes deposited stalactitic or crystallized ; its crystals being capillary, or cubes truncated on the edges or angles, of a blue colour.

Copper, combined with arsenic acid, forms several species, differing in the relative proportions and in the quantity of water in them. Five are usually enumerated, which were distinguished by Chenevix. One variety, the Octohedral Arseniate of copper, occurs crystallized in the form of an obtuse octaedron. Its usual colour is sky-blue ; sometimes apple or grass green ; it is translucent, shining ; is brittle ; has a specific gravity of 2.881. It consists of 49 of peroxide of copper, 14 of arsenic acid, and not less than 35 of water. A second, Copper Mica, or the Rhomboidal Arseniate of Copper of Phillips, is crystallized in hexaedral tables, bevelled on the terminal planes ; its colour is deep emerald-green, with much lustre and transparency ; it is less hard, and less heavy ; it consists of 58 of oxide of copper, 21 of arsenic acid, and 21 of water. A third, Right Prismatic Arseniate of Copper, as it is termed by Phillips, is crystallized in the form of an acute octaedron, the crystals being sometimes capillary ; in some specimens appearing as delicate fibres ; and sometimes in layers, flat or mammillated, and of a fibrous texture. The colour in these is dark olive-green, passing into brown or yellow, or greenish-white ; it is often transparent ; it is harder than the preceding varieties, and is much heavier. It consists of 50 of oxide of copper, from 30 to 40 of arsenic acid, with, in some varieties, 20 parts of water. The last variety occurs crystallized in triedral prisms, generally extremely small ; they are of a beautiful bluish-green colour, but from decomposition often black ; when unaltered, they are transparent. It consists of 54 oxide of copper, 30 arsenic acid, and 16 water.



Copper, in combination with sulphur, with variable proportions of other metals, forms a series of ores, which pass into each other, and which it is difficult to arrange as distinct species. Vitreous Copper Ore, or Copper Glance, appears to be the sulphuret of copper, consisting of an atom of copper, 64, and one of sulphur, 16, and often a little iron and silice. It occurs massive, disseminated, and crystallized, the forms of its crystals being numerous and often imperfect. Its colour is grey; its lustre metallic; its fracture conchoidal. The Purple or Variegated Copper Ore consists of one atom of sulphuret of iron, and two of sulphuret of copper. The colour of a fresh fracture is reddish-brown, but it quickly tarnishes; various tints of purple, blue, red, reddish-yellow, and green, being assumed and intermixed on the same surface. It occurs usually massive, with much lustre; it is soft and brittle; its specific gravity 4.9. Copper Pyrites is a combination of one atom of bi-sulphuret of copper, and two of sulphuret of iron. Its colour is brass-yellow, being deeper as the copper is more abundant in its composition; it is generally tarnished, and often iridescent. It occurs in botryoidal and stalactitic forms, and crystallized with metallic lustre. The last of these sulphurets is the Grey Copper Ore. It contains, combined with sulphur and copper, various metals, lead, antimony, silver, and iron, in very variable proportions; but these appear to be merely mixed with it, as, when present, they do not materially modify its properties, and it occurs composed almost solely of copper, iron, and sulphur. It occurs massive, disseminated, and crystallized in tetrahedrons or three-sided pyramids, variously modified. Its colour is steel-grey, which is liable to tarnish; its lustre is shining and metallic; its fracture uneven; it is brittle, and has a specific gravity from 4.4 to 4.8.



White Copper Ore is a sulphuret of copper, containing iron and arsenic, as appears from the odour it exhales when heated by the blowpipe. Its colour is white, with a shade of grey or yellow; its lustre is metallic; it occurs massive or disseminated, and is a rare ore.

#### SECT. VI.—*Of Ores of Iron.*

IRON is of all metals the one of most extensive distribution. It occurs generally in the state of oxide, pure or combined with other substances, forming an extensive series of ores.

Besides these, the singular fact has been established, that it is a meteoric or atmospheric production; the stony masses which it has been established by the most ample evidence have fallen from the clouds at different periods, and in different countries, being composed principally of iron. As natural compounds of this metal, they may be considered in this place.

These meteoric stones are heterogeneous in their structure. They have externally a thin black crust. When broken they are of an ash-grey colour, and granulated texture, and appear to be composed of four substances, which can be distinguished by a lens. One is in small globular or elliptical grains, of a grey colour, having a conchoidal fracture, a lustre resembling that of enamel, and so hard as to scratch glass; this has a resemblance in characters and composition to Chrysolite. Another consists of iron pyrites of a reddish-yellow colour, and granulated texture. The third consists of particles of iron in a metallic state, capable of being extended under the hammer, and giving to the entire stone the property of being attracted by the magnet. These three substances



are united by a fourth, which is nearly of an earthy consistence. Mr Howard carefully investigated the composition of these. Both the metallic pyrites and the iron contain nickel. The vitrified substance consists of silex, magnesia, oxide of iron, and a little nickel; with portions of alumina, lime, potash, copper, oxide of manganese and chrome: Stromeyer affirms also that cobalt is always present in meteoric iron. The composition of the earthy matter seldom varies much, and it differs principally in aggregation. The external crust consists of iron and nickel partially oxidated; in only one or two instances has the nickel been wanting. In all the specimens the same elements were found, and in proportions not very different; and this agreement in fossils, found in countries so remote, is a proof of their common origin.

There is every reason to believe, that the large insulated masses of iron which have been found in America and Siberia have had the same origin. Proust, in analysing a fragment of that from America, found it to contain nickel; Mr Howard, on repeating the analysis, likewise ascertained this, 100 grains giving  $7\frac{1}{2}$  of nickel. That from Siberia he equally found to contain nickel. And both these masses have a vitrified matter, resembling chrysolite, intermixed in their substance, analogous to that present in the meteoric stones. Other *aërolites*, as these substances have been named, have been found by Klaproth to consist of 94 or 97 of iron, with 3 or 4 of nickel.

From many of the accounts authenticated with regard to the fall of these masses, it appears that when they have been found they were highly heated, and the external crust even appeared newly vitrified. The fall has been frequently accompanied with the appearance of a fiery meteor, as of a luminous ball, and sometimes with discharges of lightning, and with a loud noise, or repeated



explosions. The *aërolites* are commonly also seen to fall, not perpendicularly, but in an oblique direction.

With regard to the origin of these masses, it is difficult to advance any hypothesis at all satisfactory. It was an obvious conjecture, that they might be projected from volcanoes; but the great height from which they have been observed to fall, (in some instances, the height of the luminous meteor accompanying the fall being calculated to be above 15 miles,) the motion nearly horizontal, which they sometimes have been observed to hold previous to their descent, their falling in countries extremely remote from any volcano, as, for example, in this country, and their entire dissimilarity to any known volcanic production, are circumstances which effectually refute this supposition. La Place advanced the bold conjecture, that they have been projected from volcanoes in the moon, and endeavoured to shew by calculation, that a force might be exerted at the surface of that planet adequate to this effect. A force sufficient to project them with a velocity of a mile and a half in a second, which is only about three times greater than the velocity of a cannon ball, would, he proved, be sufficient to throw a mass within the sphere of the earth's attraction: and this is a degree of power which there is no difficulty in supposing in volcanic eruptions. The singular appearances remarked by astronomers on the face of the moon, are also favourable to the opinion, that volcanoes of great magnitude and activity exist in that planet. This calculation, however, proceeds on the assumption, that the moon has no atmosphere. If it has, the resistance which it must oppose to the motion of a projectile would require the supposition of a force much greater than can be admitted. The opinion that the moon has no atmosphere is certainly favoured by the observations of astronomers, and by



those of Dr Wollaston, as to the other planets, already noticed : still we have no idea of volcanic power arising from any other source than combustion and the expansion of elastic fluids ; and the existence of some species of atmosphere is essential to both these causes. Other objections may also be urged against the hypothesis, as the comparatively small velocity with which the stones often fall, not penetrating more than a few inches of soil, their horizontal or oblique motion before their fall, and other phenomena attending their descent. La Place himself has lately abandoned this opinion, and inclines rather to the idea, that meteoric stones are fragments of some planet, such as that which has been supposed to have been broken into the four small planets, Ceres, Pallas, Juno, and Vesta. These fragments, it is supposed, may be moving through celestial space, and when they happen to come within the earth's attraction, are drawn to its surface. This hypothesis is even more improbable, and more at variance with the observed phenomena than the former. A more moderate hypothesis than any of these is, that they may be the products of combinations in the upper regions of the atmosphere. And in favour of this it may be remarked, that some relations have been traced between the fall of these masses, and the state of the atmosphere as connected with the weather, and the season of the year. There is also the appearance of a cloud from the part of the atmosphere whence the descent happens ; a noise too accompanies or precedes it, and frequently a luminous discharge. These facts are favourable to the opinion, that they are formed by chemical changes occurring in the atmosphere ; but it is difficult to assign even an hypothesis on this principle having any precision.

Besides these, native iron with little alloy is sometimes,



though very rarely, found in the mineral kingdom. Klaproth found a specimen to be composed of 92.5 of iron, 6 of lead, and 1.5 of copper.

The most abundant and most numerous ores of iron are those in which it is mineralized by oxygen, of which there is a series differing in the degree of oxidation of the metal, and in the intermixture of other substances. These may be arranged, principally from their chemical relations.

One species well defined is that named Magnetic Iron Ore, from its high magnetic power, or Octohedral Iron Ore. It occurs massive and crystallized; the forms of its crystals being the cube, octaedron, and rectangular tetraedral prism. Its colour is black or deep-grey; its lustre is shining and metallic; it is hard and opaque: its fracture is imperfectly foliated; it is insoluble in nitric acid, but dissolves in muriatic acid, with the assistance of heat. It appears to consist of protoxide of iron mixed with a small portion of the peroxide. Others suppose that this ore corresponds with the black oxide of iron, or is an intimate intermixture of the real protoxide and the peroxide. Sometimes it occurs in the form of small particles or grains, forming what is named Magnetic Iron Sand: this, according to Cordier, contains 14 *per cent.* of oxide of titanium.

The next species, named Specular Iron Ore, or Iron Glance, is the pure peroxide. In it the magnetic power is so far impaired by a higher degree of oxidation, that it is attracted by the magnet only when in fine powder. It occurs massive, and frequently crystallized; the forms of its crystals being very numerous, and variously modified; its colour is steel-grey, often tarnished and iridescent; the lustre shining; it is so hard as to scratch glass, and is brittle; its specific gravity is from 4.6 to 5.2. It is in-



soluble in nitric acid, but dissolves in muriatic acid with the assistance of heat. Micaceous Iron Ore is the same mineral. It is massive, or crystallized, in small and thin six-sided plates; is shining, and feels somewhat greasy, but without staining the fingers; and is not so hard as the specular iron ore. Red Iron Ore, or Red Ironstone, is also the peroxide nearly pure. There are two principal varieties of it; the compact, the fracture of which is even; and the Red Hæmatite, the fracture of which is fibrous, the fibres being straight, parallel, or diverging. The former occurs massive, or in nodules, or stalactitic, the latter almost always in globular or kidney-shaped masses. The colour of both is intermediate between brownish-red and steel-grey; but in the streak, and in powder, always blood red.

Brown Ironstone is a hydrate of the peroxide, or consists of one atom of the peroxide, and one of water. Its colour is brown in the mass, in the streak yellow, or yellowish-brown. Of it, too, there are two principal varieties, distinguished by the fracture,—the compact brown ironstone, the fracture of which is even; and the brown Hæmatite, the fracture of which is fibrous, the fibres being in general diverging. The compact occurs massive: the fibrous in nodules, stalactitic, kidney-shaped, or botryoidal. The colour of both is brown, of various shades and intensities; sometimes tarnished, so as to be iridescent, with a degree of lustre that is semi-metallic. According to D'Aubuisson, they consist of peroxide of iron 82, water 14, oxide of manganese 2, silex 1. They yield from 40 to 60 of metallic iron, in general of excellent quality, from 100 of ore. With these are connected the less important varieties of Scaly Iron Ore, and of Iron Ochre;—the former incrusting the other ores, or lining their cavities, and being composed of scaly particles, which have a shining lustre, and feel unctuous; the latter



being earthy, of a red or yellowish-brown colour, dull, and staining the finger.

Black Ironstone, like the red and brown, comprises two principal varieties,—the compact, and the fibrous or black Hæmatite. Its colour is bluish-black, or dark steel-grey, with a semi-metallic lustre. It occurs massive, and in tuberosc, kidney-shaped, and botryoidal pieces. Its composition is not known, but it must contain a large proportion of oxide of manganese, as it colours borax blue before the blowpipe.

Argillaceous Iron Ore, or Clay Ironstone, comprises a series of ores, in which oxide and carbonate of iron are mixed with variable proportions of argil and silex. The common clay ironstone occurs massive, generally in beds or strata. Its colour is grey, passing into yellowish or reddish-brown, especially from exposure to the air; it is dull and opaque; its fracture is earthy, sometimes inclining to slaty; it is soft, and feels meagre. The ores of this family have been generally supposed to consist of oxide of iron and clay, but Mr Phillips has found that clay ironstone consists of 72 carbonate of iron, with only 18 of silex and alumina, and a little lime and carbonaceous matter. They afford from 30 to 40 of iron in 100, of good quality. Nodular Ironstone, reniform iron ore, or Eagle stone, belongs to this species; it occurs in rounded masses, composed of concentric lamellar concretions, and sometimes inclosing a nodule slightly adhering or quite loose. Pisiform Iron Ore is a similar variety, in small rounded grains, whence its name; of a yellowish-brown colour, having an earthy fracture. Pitch Iron Ore occurs in layers of a greyish-black colour, with resinous lustre. It consists of oxide of iron and water, with a little sulphuric acid.

Sparry Iron Ore is a species well determined from its



chemical relations. It usually consists of carbonates of iron and manganese, and carbonate of lime, but in variable proportions. The proportion of carbonate of lime augments even in some varieties so much, that they are placed among the calcareous fossils, forming the Pearl Spar; and it is only when the proportion of metallic matter is abundant, that it is regarded as an iron ore. It occurs massive, disseminated, and crystallized; the forms of its crystals being the rhomb, perfected or truncated, the lens, the octaedron, and the dodecaedron. Its colour is white, grey, yellow, or brown; but what is a peculiar property of it, the colour darkens on exposure to the air, from absorption of oxygen by the metallic matter; it thus becomes brown, and at length black; its lustre is pearly; its fracture is foliated: its fragments are rhomboidal; it scratches calcareous spar; its specific gravity is 3.6; it is soluble with effervescence in acids. It has been found nearly pure, composed of 57 protoxide of iron, and 35 of carbonic acid; but usually the quantity of intermixed lime and manganese is considerable. This ore is considered as affording the iron best adapted to the manufacture of steel.

Oxide of iron deposited from stagnant water, in swampy situations, forms Bog or Swamp Iron Ore, which is in masses corroded, cellular, and sometimes tuberoso, of a yellow or brown colour, dull, and earthy; it often contains a number of other ingredients, particularly phosphoric acid. Blue Iron Earth is of similar origin; it consists chiefly of phosphate of iron, with variable proportions of water, alumina and silex; its colour is indigo blue; it is massive, friable, and without lustre. Green Iron Earth is a similar compound: it is earthy, of a green colour, without lustre. Pure proto-phosphate of iron forms a mineral of a deep blue colour, in small plates ad-



hering slightly, the surface of which is brilliant; they are translucent, but some, apparently from the loss of water, are opaque: it contains two or three atoms of water.

Iron mineralized by arsenic acid forms an ore, formerly regarded as an arseniate of copper. It occurs usually crystallized in small cubes, translucent, smooth, and highly shining, the lustre being adamantine; the colour is dark green, sometimes with a brown or yellowish tinge: the fracture is imperfect foliated. By the analysis of Chenevix, it consists of one atom of arsenic acid, two of protoxide of iron, and three of water. Another arseniate of iron, with 27 *per cent.* of oxide of iron, occurs in minute crystals, of a faint sky-blue colour; transparent, and of very high lustre, and generally grouped irregularly, sometimes united so as to assume a mammillary form.

Sulphate of Iron occurs in tuberosse masses; also in green capillary crystals, in imperfect rhombs, or in octaedrons, easily recognised by its solubility in water, its astringent taste, and the usual tests of the salts of iron.

Bi-sulphuret of Iron forms a well-defined species, known under the name of Iron Pyrites. It occurs massive, disseminated, and often crystallized in cubes regular, or modified by truncation of the angles or edges, or acumination of three planes on the angles. Its colour is brass-yellow, and the lustre metallic; it is opaque; the fracture is uneven; it is brittle; its hardness is such as to strike fire with steel. By friction it exhales a sulphureous smell. This odour is strong when it is heated before the blowpipe: it gives also a blue flame. It consists of two atoms of sulphur, 32, and one of iron, 28. There are some varieties of this species, differing in structure or form. The Striated or Radiated Pyrites presents a striated fracture, the striæ being diverging. Capillary pyrites occurs in capillary crystals, slightly flexible, having a me-



tallic lustre, and a colour passing from yellow to steel-grey. Hepatic Pyrites, so named from the liver-brown colour which it assumes from exposure to the air, occurs massive, of various imitative forms, and crystallized in six-sided prisms, or six-sided pyramids; has less lustre than the others, and is more subject to decomposition.

Magnetic pyrites, distinguished, as the name implies, by its magnetic quality, is the protosulphuret. Its yellow colour is deeper, and approaching to brown, often tarnished; its lustre is inferior; its fracture compact.

#### SECT. VII.—*Of Ores of Lead.*

LEAD occurs principally mineralized by different acids, and by sulphur.

Carbonate of Lead, the White Lead Ore of mineralogists, is presented under different forms,—earthy, indurated, and crystallized. The figures of its crystals are the hexaedral prism, the tetraedral prism, the double hexaedral pyramid, the four and the six-sided table: it occurs also in acicular crystals aggregated. The lustre is splendid and adamantine; the colour white, sometimes grey, yellowish, or brown; it is translucent, brittle and soft, so as to be easily scratched by the knife. The specific gravity is from 6 to 7. Urged by the flame of the blowpipe, it decrepitates, becomes yellow or red, and melts into a metallic globule. It effervesces with acids, and in diluted nitric acid is dissolved. A pure specimen of it was found by Klaproth to be composed of 82 of protoxide of lead, 16 of carbonic acid, and 2 of water; but it often contains foreign ingredients intermixed.

Earthy Lead Ore, which occurs friable or indurated, of a grey colour, dull and opaque, appears to be a mix-



ture of carbonate of lead with various earthy matters. When associated with an ochrey earth, so as to assume a red colour, it has been named Native Minium. Black Lead Ore appears to be carbonate of lead, altered probably by the action of sulphur, or by intermixture with it, especially as it is found generally incrusting the native sulphuret, and is itself incrusting by the carbonate. A lead ore, which occurs crystallized in cubes, similar in appearance to carbonate of lead, but softer, and having less specific gravity, was found by Chenevix to contain both carbonic and muriatic acid, or it was a murio-carbonate of lead. An ore of somewhat similar nature, found at Mendip in Somersetshire, has lately been described by Berzelius: it is of a pale straw colour, with a foliated fracture; heated on charcoal it is reduced to metallic lead, fumes of muriatic acid being evolved; it consists of chloride of lead 34, oxide of lead 55, and carbonate of lead 7.

Sulphate of Lead occurs usually crystallized in octaedrons, modified by truncation or bevelment. Its colour is white, with shades of grey; the crystals are transparent; their lustre shining and adamantine; the fracture compact; the specific gravity 6.3. It does not effervesce with acids, and is not soluble in nitric acid.

Connected with the carbonate and sulphate are several new Ores of Lead, interesting from their composition, which have been lately discovered at Leadhills, and also in Spain. These are the Sulphato-carbonate of lead, the Sulphato-tri-carbonate of lead, the Cupreous Sulphate of lead, and the Cupreous Sulphato-Carbonate of lead. The first of these consists, according to Mr Brooke, of 46.9 of carbonate, and 53.1 of sulphate of lead. It occurs in oblique four-sided prisms of an adamantine lustre, greenish or yellowish white colour, translucent, sectile, and having a specific gravity of 7. It is partially



dissolved by nitric acid, effervescing, though not very perceptibly. The Sulphato-tri-carbonate of lead appears, as analysed by Mr Brooke and Stromeyer, to consist of carbonate 72.5, and sulphate of lead 27.5; or of three atoms of the former, and one of the latter. It occurs crystallized in acute rhomboids of a yellowish-white colour, passing into green and brown, with a resinous lustre approaching to adamantine; it is transparent or translucent; its specific gravity 6.26. It effervesces briskly in nitric acid, and leaves a white residue. The Cupreous Sulphate of lead occurs in prismatic crystals, frequently in twin crystals. It is of a deep and beautiful azure blue colour, with an adamantine lustre, and slightly translucent. It consists, according to Mr Brooke, of two atoms of sulphate of lead, and one of hydrate of peroxide of copper. Lastly, the Cupreous Sulphato-carbonate of lead occurs in broad rectangular four-sided prisms, of a deep verdigris green colour; its lustre is resinous, it is translucent; the fracture is uneven; the specific gravity 6.4; it consists of 55.8 of sulphate, 32.8 of carbonate of lead, and 11.4 of carbonate of copper.

Phosphate of lead is a common ore. Its usual colour is green; but it passes through yellowish-green into pure yellow. It occurs in incrustations, often mammillary or botryoidal, composed of minute crystals aggregated, the form of which is the hexaedral prism, truncated or acuminate, and the hexaedral pyramid. They have a waxy lustre, and are translucent; the fracture is uneven; it is brittle and soft. It does not decrepitate before the blowpipe, but becomes white, and melts into a globule of a grey colour, without the lead being reduced. It does not effervesce with nitric acid, but is dissolved by it. A variety of this species, containing a little chlorine, named Brown Lead Ore, occurs massive, and crystallized in hexaedral prisms, having a waxy lustre, and opaque.



An ore of lead occurs in mammillary masses of a yellowish-green colour, which contains both phosphoric and arsenic acid. Lead, too, occurs mineralized by arsenic acid alone. Its colour is brown or green passing into yellow; it occurs in acicular or capillary crystals, and also massive; by Mr Gregor's analysis, it is a sesqui-arsenate of lead. Another variety of native arseniate of lead, with an intermixture of iron, occurs in uniform masses of a rough surface, of a yellow colour, opaque and dull. These are all distinguished by the strong arsenical odour they give when heated on charcoal by the blowpipe.

Yellow Lead Ore is a species, in which the lead is mineralized by a metallic acid,—the Molybdic Acid. It occurs commonly in small crystals, the forms of which are, rectangular tables of four or eight sides bevelled, the cube, the octaedron, and double eight-sided pyramid: its colour is yellow, and its lustre waxy. It decrepitates before the blowpipe, and melts into a globule of a grey colour, in which are disseminated particles of metallic lead; is insoluble in nitric acid. It is molybdate of lead with a little iron and silice.

Chromate of lead belongs rather to the ores of chrome.

Tungstate of lead occurs in Bohemia, in very acute four-sided pyramids of a brown colour.

Lead, mineralized by sulphur, forms the most abundant ore of the metal, that named Galena. It occurs massive, disseminated, incrusting, in corroded masses, and crystallized. The forms of its crystals are the cube, the octaedron, the tetraedral prism, the hexaedral prism, and the three-sided table, perfect or modified. Its colour is bluish or lead grey, sometimes iridescent on the surface. Its lustre is splendent and completely metallic; it is opaque; its fracture is distinctly foliated; its fragments are of a cubical form: it is soft, so as to be easily scratched; it is



also easily frangible. It decrepitates before the flame of the blowpipe, melts, exhales a sulphureous odour, and affords a globule of lead. In general, it consists of one atom of lead, and one of sulphur. It always contains a small quantity of silver, with iron, silex, and lime. One variety, which is of an even fracture, Compact Galena, contains a little sulphuret of antimony. There is another in which the quantity of sulphuret of antimony is so large, that it forms a distinct species; it is of a grey colour, occurs massive, and sometimes crystallized in the form of a cube. It has been named Bournonite, from Count Bournon; and consists of sulphurets of lead and antimony, with smaller portions of sulphurets of copper and iron.

An ore of lead has lately been analysed by Stromeyer, which was found to be a seleniuret, consisting of selenium 28, lead 71, cobalt 0.8. It resembles galena, but has a more perceptible blue tint; it is crystalline, with metallic lustre; when heated it gives out the peculiar odour of selenium.

#### SECT. VIII.—*Of Ores of Tin.*

TIN occurs in nature in the state of the oxide nearly pure, and in smaller quantity in that of sulphuret.

Native Oxide of Tin, or Tinstone, occurs massive, disseminated, and in crystals; the forms of which are numerous, and complicated. Its colour is brown, of various shades: its lustre is highly splendent; when of a dark colour, it is opaque; when of a lighter shade, translucent; it is hard and brittle. Heated on charcoal before the blowpipe, it is reduced. A specimen analysed by Klaproth gave 99 of oxide of tin in 100. Wood Tin Ore consists of oxide of tin, with from 5 to 10 *per cent.* of oxide



of iron. It is found in small rolled pieces, having a distinctly fibrous fracture. Its colour is brown; its lustre glistening; it is opaque and hard.

Tin mineralized by sulphur forms Tin Pyrites. It occurs massive or disseminated; its colour is grey; its lustre metallic and glistening; it is opaque; it has a specific gravity of 4.350. It is composed of 25 of sulphur, 34 of tin, 36 of copper, and 2 of iron.

#### SECT. IX.—*Of Ores of Zinc.*

ZINC is mineralized by oxygen, carbonic acid, sulphuric acid, and sulphur.

Its most abundant ore, Calamine, includes two species, very similar to each other in characters, but not in composition. One is a siliceous oxide of zinc, composed of silex 26, oxide of zinc 66, and water 7. The other is carbonate of zinc, which is sometimes met with quite pure. The siliceous oxide often occurs in small prismatic crystals; its specific gravity is only 3.3; it becomes electric when heated, and is dissolved by acids, forming a gelatinous solution. The carbonate occurs sometimes crystallized in minute obtuse rhomboids; its specific gravity is 4.42, and it is dissolved by acids with effervescence. In other respects they are very similar. They frequently occur, sometimes highly indurated, of a compact or striated texture; often also cellular or corroded, or botryoidal. Their colour is white, but with various shades of yellow; they are dull; the crystals are semi-transparent; the earthy is opaque.

A red ore of Zinc has been found in the United States of America, which consists of the oxide, with small portions of oxides of manganese and iron: it is massive, hard, brittle, and has a foliated fracture.



Oxide of zinc combined with alumina forms a mineral, Automalite, so hard that it has been mistaken for a variety of corundum. It occurs in crystals of a dark green colour, vitreous, and conchoidal fracture; it consists of argil 60, oxide of zinc 24.

Sulphate of zinc occurs with the sulphuret, tuberoso or stalactitic, of a greyish colour, and translucent; and distinguished by solubility in water, and its styptic taste.

Blende, or native sulphuret of zinc, presents several diversities in appearance. From difference of colour, three sub-species have been formed, the yellow, the brown, and the black. The brown blende is the most common; its colour is brown, with shades of yellow and red, and often tarnished; its lustre inclines to resinous; its fracture is foliated, sometimes fibrous; its specific gravity is from 3.7 to 4. It occurs massive, and often in crystals of numerous and complicated forms. Yellow Blende has a yellow colour passing into green or red; its lustre is rather greater, and is adamantine; and when the colour is light, it is semi-transparent. Black Blende has a black colour with a shade of brown or red; its lustre is metallic; its fracture foliated. Blende, besides sulphuret of zinc, contains frequently a portion of water, also iron, and often silex, alumina, sometimes lead, arsenic, silver, or copper. The yellow variety, according to Bergman, contains fluoric acid. A species of Blende occurs of a fibrous structure, and brown colour, which contains Cadmium.

#### SECT. X.—*Of Ores of Nickel.*

NICKEL occurs alloyed with arsenic, and also in the state of oxide. The first species, the Kupfer-nickel of mineralogists, is the most abundant. It occurs massive



and disseminated; its colour is copper red, of various shades; its lustre weakly shining; its fracture is uneven; it is hard and not easily broken. Before the flame of the blowpipe, it gives arsenical vapours. It dissolves in acids, giving a green solution. According to Stromeyer, it consists of nickel 44, arsenic 54, often with portions of iron, cobalt, and copper.

Oxide of nickel occurs as an incrustation, sometimes disseminated, of a friable texture and earthy appearance; of an apple-green colour, without lustre. Its solution in acids is of a green colour. It occurs generally with kupfer-nickel, or with certain cobalt ores. The pure sulphuret of nickel forms a mineral called Hair Pyrites.

#### SECT. XI.—*Of Ores of Cobalt.*

THE ores of cobalt are distinguished by giving to borax, when fused with it by the blowpipe, a blue colour, and forming, when dissolved in nitric acid, a solution which becomes green from heat.

White Cobalt Ore consists principally of cobalt and arsenic. Its colour is tin-white, liable to tarnish, with little lustre. It occurs massive, and crystallized in cubes, and in octaedrons; the fracture is uneven; it is hard and brittle. Before the blowpipe it melts, and gives an arsenical smoke and odour; it forms a metallic globule, and gives to borax a blue colour. The Shining Cobalt Ore, or Cobalt Glance, appears to be the same mineral.

Grey Cobalt Ore is an alloy of cobalt with arsenic and iron; sometimes with small portions of nickel and bismuth. Its colour is light grey, liable to tarnish; its lustre weakly shining and metallic: it occurs massive or disseminated; its fracture is even. Before the flame of the blowpipe, it gives an arsenical odour and smoke.



Oxide of Cobalt occurs in a loose form, or of various degrees of induration, dull, earthy, and soft. It is of different colours, from the intermixture of oxide of iron, and other metallic oxides; whence varieties, distinguished by the names of Black, Brown, and Yellow Cobalt Ochres. These all give a blue colour to glass or to borax when fused with it, and sometimes exhale an arsenical odour.

Red or Peach Bloom Cobalt Ore derives its name from its colour, which is a beautiful red, similar to that of the peach blossom, passing, however, into other shades of red, and from decomposition into other colours. It occurs massive, disseminated, and in minute crystals. One variety has an earthy fracture, without lustre, and occurs as an incrustation. Before the blowpipe both varieties lose their colour, become grey, and give a weak arsenical odour; borax receives a rich blue colour. This species is an hydrated arseniate of cobalt.

## SECT XII.—*Of Ores of Manganese.*

THE principal ore of manganese is the Black Oxide. It occurs massive, or in rhomboidal crystals. Its usual colour is steel-grey, inclining to brown or black, and varying in its lustre: when crystallized, the surface of the crystals is shining: when amorphous, dull. Its texture is radiated, foliated, compact, or earthy. All the varieties have the same chemical characters. They are not melted by the blowpipe, but assume a brown colour. To borax they communicate by fusion a violet-blue colour. With sulphuric acid they yield oxygen gas, on the application of a moderate heat, and they liberate chlorine from muriatic acid. The radiated variety appears to be the pure oxide, combined with about 7 *per cent.* of water;



there are also frequently present oxide of iron, carbonate of lime, silice, and barytes. The earthy variety contains the largest proportion of oxide of iron; and what has been named Black Wad, which occurs as an earthy incrustation, consists of 43 of oxide of manganese, and 43 of oxide of iron.

Oxide of manganese, combined with carbonic acid, forms an ore of a red colour, inclining to brown, with a pearly lustre; its crystals are usually lenticular; it occurs also in globular and botryoidal masses.

Oxide of manganese, probably in a less high state of oxidation, is the basis of the Red Manganese Ore. Its colour is rose-red, more or less pale, passing, from exposure to the air and light, to light yellow, or even to white. It has little lustre or transparency; occurs massive and disseminated. Before the flame of the blowpipe it does not melt, but acquires a dark-grey colour: to borax it gives, by fusion, a violet tinge. It consists of from 52 to 60 of oxide of manganese, from 30 to 40 of silice, and small portions of lime, alumina, and iron. Bi-sulphuret of manganese forms an ore of a black colour, shining lustre, opaque, soft, and massive. Phosphate of manganese and iron occurs massive, of a brownish-black colour, resinous lustre, and semi-transparent in thin pieces.

### SECT. XIII.—*Of Ores of Arsenic.*

ARSENIC is found native, pure, or alloyed with other metals; also mineralized by sulphur, by oxygen, and in the state of acid combined with lime.

Native arsenic is of a white colour, with a slight shade of grey, with metallic lustre; but tarnishes quickly on exposure to the air; its fracture is uneven; it is very brit-



tle, and has a specific gravity of 5.6 or 5.7. It generally contains a portion of iron, with sometimes antimony.

Arsenic alloyed with a larger quantity of iron, and a small quantity of sulphur, constitutes the species named Arsenical Pyrites or Mispickel. The colour of its fresh fracture is white, and the lustre shining, but it quickly tarnishes, and becomes yellow and iridescent. It occurs massive, disseminated, and often crystallized in tetraedral prisms, and octaedrons very acute; it is hard and brittle. Argentiferous Arsenical Pyrites differs little from the preceding species: its colour is silver white, with a yellow tarnish, its lustre metallic: with arsenic and iron it contains a portion of silver, varying from 1 to 10 *per cent*.

Arsenic, mineralized by sulphur, forms two ores, named Orpiment and Realgar. The proto-sulphuret, Realgar, is of a red colour, inclining to scarlet, sometimes to orange. It occurs massive, and crystallized in oblique tetraedral or hexaedral prisms, generally small, and translucent, with a shining lustre. It exhales before the blowpipe a white arsenical smoke, with an arsenical and sulphurous odour, and gives a blue flame. The sesqui-sulphuret orpiment is of a yellow colour, with a highly shining lustre, is semi-transparent when in thin leaves. It occurs massive, and in very minute crystals: its fracture is foliated; it is soft and somewhat flexible: it exhibits the same appearances before the blowpipe as the red sulphuret.

Oxide of arsenic occurs as an incrustation on other ores, friable or little indurated, sometimes botryoidal, or in minute crystals. It is white, with shades of yellow or grey, and dull; its taste is acrid, and it is soluble in water.

Arseniate of Lime forms the ore named Pharmacolite. This occurs as an incrustation, botryoidal, or in capillary crystals, of a white colour, with a shade of red, and with a silky lustre; its fracture is striated or fibrous; it is



soft, so as to soil; and light, the specific gravity being 2.5 or 2.6. It dissolves in nitric acid without effervescence, and gives the arsenical odour by the blowpipe.

#### SECT. XIV.—*Of Ores of Bismuth.*

BISMUTH occurs native, also mineralized by oxygen, and by sulphur. Native Bismuth has nearly the properties of the pure metal. Its colour is white, verging to red, and often tarnished, with metallic lustre; its fracture is foliated: it occurs massive, sometimes crystallized, in four-sided tables, or cubes, small and indistinct. It melts even in the flame of a candle. It dissolves in nitric acid, and its solution is decomposed by the affusion of water.

Oxide of bismuth occurs in an incrustation of a yellowish-grey colour, earthy, and dull; sometimes indurated, having a foliated fracture; opaque and soft.

Sulphuret of bismuth occurs massive, disseminated, and in capillary crystals, of a light grey colour, and shining lustre. It melts in the flame of a candle, and when heated, exhales sulphureous fumes.

#### SECT. XV.—*Of Ores of Antimony.*

THIS metal is found native, also combined with oxygen, chlorine, or sulphur. Native Antimony is of very rare occurrence. It has the characters of the metal, and contains a minute portion of silver and iron.

Antimonial Ochre, as it has been named, occurs as an earthy-like incrustation, of a straw-yellow colour, and has been supposed to be an oxide. Another ore of more uniform composition, is the White Antimonial Ore, occur-



ring in acicular crystals, grouped and divergent, so as to form a stellular appearance, and likewise in tables and in cubes, of a snow-white colour, silky lustre, translucent and soft. It consists of 86 of oxide of antimony, 3 oxides of antimony and iron, and 8 of silex.

The Sulphuret is the principal antimonial ore. It occurs massive, disseminated; or in acicular or prismatic crystals, often aggregated. Its colour is lead-grey, frequently tarnished or iridescent; its lustre is shining; its fracture is striated or radiated, in one variety it is foliated, uneven. It melts easily before the blowpipe, and exhales fumes of sulphur and oxide of antimony. It consists of one atom of antimony, 44, and one of sulphur, 16. Plumose Grey Antimonial Ore contains, with sulphuret of antimony, portions of arsenic and iron, and sometimes a little silver. It occurs generally in capillary crystals.

Red Antimonial Ore is composed, according to M. Rose, of one atom of the protoxide united with two atoms of the proto-sulphuret. It occurs in capillary crystals of a red colour, opaque, and shining. It melts before the blowpipe, and is volatilized.

#### SECT. XVI.—*Of Ores of Tellurium.*

THIS metal occurs chiefly alloyed with other metals.

In its purest state it forms an alloy formerly named Aurum Paradoxicum, consisting of tellurium 92, iron 7.2, gold 0.25. It is disseminated, or in small crystals of a white colour, and shining metallic lustre, having a foliated fracture, and a specific gravity from 5.7 to 6.1. It melts before the blowpipe, gives a white smoke, and is oxidized.

In the graphic gold ore already described, about 60 *per cent.* of tellurium are present.



The white or yellow Sylvanite contains, besides tellurium, gold, silver, and lead. Its colour is silver white; its lustre metallic; its fracture foliated; its specific gravity 10.6. It occurs disseminated, or in minute crystals.

The black tellurium ore consists, according to Klaproth, of tellurium 82, lead 5.4, gold 9, copper 1.3, silver 0.5, and sulphur 3. It occurs massive, and crystallized in six-sided tables; it is blackish-grey; its lustre metallic; its fracture foliated; its specific gravity 8.9. It melts before the blowpipe, and is partly volatilized.

#### SECT. XVII.—*Of Ores of Chrome.*

THE chief ores of Chrome are the Chromate of lead, and that in which its oxide or acid is united with oxide of iron.

Chromate of Lead, the Red Lead ore of mineralogists, is usually crystallized in rhomboidal four-sided prisms. Its colour is aurora red, its lustre shining and adamantine: it is translucent; its specific gravity is 6. It consists of 68 of oxide of lead, and 32 of chromic acid.

Chromate of iron, as it is commonly though incorrectly called, occurs massive, and in octohedrons, is of a dark-brown or black colour, dull, and opaque; hard, difficult to break, with an uneven fracture; its specific gravity is 4. It consists, according to Klaproth, of protoxide of chrome 55.5, protoxide of iron 33, alumina 6, silex 2. It occurs near Baltimore in North America; in Unst, one of the Shetland islands; and in France. The ore from Baltimore contains, according to M. Seybert, 39.5 of protoxide of chrome, 36 of peroxide of iron, 13 alumina, and 10.5 silex. The Shetland ore appears to contain a larger quantity of the oxide of chrome; it is now extensively used in the preparation of chromate of



potash to be employed in dyeing, and the formation of pigments.

SECT. XVIII.—*Of Ores of Molybdenum.*

THERE is only one ore of this metal—the bi-sulphuret. It occurs massive, disseminated, and sometimes crystallized in hexaedral prisms or tables. Its colour is lead-grey, its lustre metallic, its fracture is foliated; and it is easily split; it is soft, so as to soil; and feels unctuous.

SECT. XIX.—*Of Ores of Tungsten.*

THE mineral commonly named Tungsten is a tungstate of lime, consisting of one atom of tungstic acid, and one of lime, with a little silica and iron. It occurs massive, and in octaedral crystals. Its colour is yellowish or greyish white; its lustre shining and vitreous; it is soft, and has a foliated fracture.

The other species of this genus is the mineral named Wolfram. It occurs massive and crystallized in broad hexaedral prisms, or four-sided tables. Its colour is black, its lustre shining; it is opaque; its fracture is foliated. It consists of tungstic acid 78, oxide of iron 18, and of manganese 6; or it is commonly called tungstate of iron or manganese.

SECT. XX.—*Of Ores of Titanium.*

UNDER this genus are placed several species, differing much in external characters.



Rutile, Titanite, or Red Shorl, is nearly pure peroxide of titanium. It occurs crystallized in prisms, often capillary, and penetrating quartz; its colour is reddish; its lustre shining; it is hard and brittle, and has a foliated fracture.

Sphene, which occurs in rhomboidal four-sided prisms and octohedrons of a reddish-brown colour, passing sometimes into yellow or green, consists of three atoms of silicic acid, two of lime, and three of peroxide of titanium.

Oisanite, octahedrite, or blue shorl, is regarded by Vauquelin as a pure oxide of titanium, differing from rutile in being free from iron. It is crystallized in acute octohedrons; its colour is blue, passing into brown; its lustre adamantine; it is translucent; its fracture is foliated.

Menachanite occurs in grains or sand, of a greyish-black colour, opaque, with semi-metallic lustre, having a specific gravity of 4.4, and weakly attracted by the magnet. It consists, according to Thomson, of one atom of peroxide of titanium, and one of protoxide of iron. Nigrine is also in angular grains of a brownish-black colour, with little lustre, and opaque; it is not attracted by the magnet; it contains four atoms of peroxide of titanium and one of protoxide of iron. Iserine occurs likewise in angular grains of a black colour and weak lustre, and opaque, having a specific gravity of 4.5.

#### SECT. XXI.—*Of Ores of Uranium.*

THE mineral named Pechblende or Pitchblende, is the ore in which this metal was first discovered. It is generally massive, of a black colour, with resinous lustre,



opaque, brittle, and soft; having a specific gravity of 7.5. It consists chiefly of protoxide of uranium, and oxide of iron.

Green Mica, or Micaceous Uranitic Ore, occurs in thin leaves, or in minute four-sided tables; its colour is green; its lustre shining, with transparency; its fracture is foliated; and it is soft and easily broken. It has usually been regarded as composed of oxides of uranium and copper, with a portion of water. The green uranite of Cornwall has, however, been found by Mr Phillips to consist of 73 phosphate of peroxide of uranium, 12 phosphate of copper, and 14 water. Some sulphates of uranium have been found native by Berzelius.

Uranitic ochre occurs as an incrustation or efflorescence, of a straw-yellow colour, without lustre, opaque, soft, and friable. It is oxide of uranium nearly pure, containing sometimes a little oxide of iron.

#### SECT. XXII.—*Of Ores of Columbium or Tantalum.*

THE mineral named Tantalite or Columbite, consists, according to Berzelius, of oxide of tantalum with small portions of oxides of manganese and iron. It occurs in imperfect octahedral crystals of a black colour, with an internal metallic lustre; hard so as to give sparks with steel, and having a specific gravity of 7.9. Ytthro-tantalite is composed of oxide of tantalum 57, tungstic acid 8, yttria 20, lime 6, and oxide of iron 3.5; it is in small imbedded masses of a black colour, with metallic lustre; having a granulated fracture, and a specific gravity of 5.1.



SECT. XXIII.—*Of Ores of Cerium.*

IN a mineral named False Tungsten, the metal Cerium was first discovered. It has since been named Cerite. It occurs massive or disseminated; of a flesh-red colour, semi-transparent; and having, in the fresh fracture, considerable lustre; it is so hard as to strike fire with steel; and has a specific gravity of from 4.7 to 4.9. It consists of oxide of cerium 68.6, silex 18, lime 1.25, oxide of iron 2, water and carbonic acid 9.6.

Ytthro-cerite occurs massive, of a grey, violet, or red colour; opaque, with glistening lustre; its fracture is foliated, and its specific gravity about 2.4. It consists of from 16 to 18 of oxide of cerium, with 50 of lime, 8 of yttria, and 25 of fluoric acid.

Dr Thomson found in another mineral, which he has named Allanite, 34 *per cent.* of oxide of cerium, with oxide of iron and silex. It is crystallized in prisms, of a brownish-black colour, resinous lustre, opaque, and brittle. It swells before the blowpipe, and melts imperfectly; forms a jelly with acids. It is from Greenland.

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CHAP. IV.—OF INFLAMMABLE MINERALS.

UNDER this order are placed those minerals not metallic, which have the property of inflammability. They admit of being arranged under three genera, resting on chemical distinctions. Sulphur constitutes one genus. Under a second may be placed those composed of Carbon principally,—the Diamond, Plumbago, and Coal. To a third



I have referred the Bitumens: these consist chiefly of carbon and hydrogen, forming a series in which these principles are combined in different proportions, the hydrogen being usually predominant.

#### SECT. I.—*Of Native Sulphur.*

SULPHUR occurs in the mineral kingdom principally as a volcanic product, though it is also found not of volcanic origin. It is usually pure, of its characteristic yellow colour, semi-transparent, with shining lustre; it occurs disseminated, or crystallized in pyramids, octohedrons, or dodecaedrons under various modifications. It also occurs in masses, and as a light sublimate. Its other properties are those of pure sulphur.

#### SECT. II.—*Of Carbonaceous Minerals.*

OF these the Diamond is the purest. From its external characters it has been placed among the earthy fossils; but as it is combustible, and its nature perfectly ascertained, there can be no hesitation in placing it among the inflammable minerals, though it differs widely from the other substances with which it is associated. This gem has been already described, (vol. i. p. 585.) It occurs crystallized in octohedrons and dodecahedrons, variously modified, and generally imperfect. It is not met with in its original situation, but in the beds of streams, or in a loose ferruginous sand beneath the soil.

PLUMBAGO, or GRAPHITE, it has been mentioned, is a carburet of iron. When pure, it consists of 91 of carbon, and 9 of iron. Graphite occurs massive, or disseminated;



its colour is black, or dark steel-grey; its lustre weakly shining; it is opaque; its fracture is foliated, or slaty; it is soft, soils the fingers, and feels unctuous. It burns with difficulty, leaving oxide of iron as a residuum, mixed with alumina and silex.

COAL consists essentially of carbonaceous matter; and in one variety, the blind coal, this is nearly pure; but in the greater number of the varieties of coal, there is present a soft bituminous matter, which communicates to them some peculiar properties. Those which contain much bitumen are highly inflammable, take fire readily, and burn with a bright flame; those in which the carbon predominates burn less vividly; the latter require a higher heat to kindle them, and burn without flame, or only with a red glow. Numerous varieties of coal exist, deriving distinctions partly from their state of aggregation, but principally from the proportions of their bitumen and carbon. The series may be briefly described, as they are connected, on the one hand, with vegetable matter, and on the other, with carbon not of vegetable origin.

BLIND COAL, the Anthracite of mineralogists, the Glance Coal of Werner, consists almost entirely of carbon, with a little earthy matter and iron, and forms the connection of coal with plumbago. It burns with difficulty, without flame, without exhaling any bituminous odour, and without softening or caking; its colour is black; its fracture is conchoidal or slaty. It occurs often in primitive rocks, or in those of transition, in imbedded masses, in beds and veins; and there appears no reason to infer that it is of vegetable origin.

BLACK COAL, as it is named by Werner, is the common coal, of which there are several varieties. That which is of a slaty fracture is the variety most abundant in this country; its principal fracture is slaty, the cross fracture



small grained uneven ; its colour is black, frequently with a shade of grey ; its lustre is resinous ; it is soft and brittle, and has a specific gravity of about 1.25. It softens, cakes, and burns brightly, and leaves, when burnt, a small residue of ashes. It contains a proportion of bitumen, varying, however, so much as from 24 to 40, with from 53 to 70 of carbon, and 2 or 3 of earthy matter and oxide of iron. According to Dr Thomson, the kind of coal which cakes when heated, consists of carbon 75, hydrogen 4, nitrogen 16, and oxygen 4.6 ; the common slaty coal he states to be composed of carbon 75, hydrogen and nitrogen each 6.25, and oxygen 12.5. He does not suppose the bitumen to exist ready formed in coal, but rather concludes, that coal is a definite compound of carbon, hydrogen, oxygen, and nitrogen, in atomic proportions. Foliated coal approaches to the slaty, being distinguished by its fracture and its greater lustre ; it is softer, and appears to contain more bitumen. Columnar coal is so named from occurring in columnar distinct concretions, and is more rare. Cannel coal is distinguished by its smooth conchoidal fracture ; it has a resinous lustre and black colour, and burns at first with a clear light, which, however, soon ceases. It contains about 75 of carbon, with 22 of bitumen, and 3 of foreign matter, or, according to Dr Thomson, 64.7 of carbon, 21.5 of hydrogen, 13.7 of nitrogen, without any oxygen. The results obtained by Dr Thomson, relative to the constitution of coal, are rather singular, from the large quantity of nitrogen which he detected in it. Dr Ure has given a different result with regard to the slaty and cannel coal, finding no nitrogen in either of them, a statement which Dr Henry regards as incorrect, since all the specimens of these varieties subjected by himself to examination, yielded ammonia by distillation. Dr



Ure has farther estimated, and apparently with more justice, the proportion of oxygen in these coals at from 21 to 24 *per cent.* Pitch coal has a smooth conchoidal fracture, with resinous lustre, and a deep black colour; from the closeness of its texture it takes a polish, and forms what is named Jet.

BROWN COAL has an imperfect conchoidal fracture, sometimes fibrous and woody, is soft and light; it burns with a blue flame; it occurs with some of the following varieties, in alluvial land: it contains little bitumen. Connected with this is what is named Earthy Bituminous Wood, or Earthy Coal, which is found of a loose consistence, dull, of a blackish-brown colour, light and soft. The last of the series, or that most evidently of vegetable origin, is Bituminous Wood. The ligneous texture is distinctly marked, and even the external shape of the branches and stems of trees, and the annual rings of the wood, are preserved, so as to resemble wood imperfectly charred. Its colour is brown, of different shades; it has little density or hardness, and is so light as nearly to float on water. It burns with a clear flame, and with a bituminous odour, and leaves a small quantity of white ashes.

Coal, excluding the anthracite or blind coal, has been supposed to be of vegetable origin. There is a gradation from bituminated wood; in some varieties the structure, and even the remains of plants, are apparent; and its chemical composition agrees with that of vegetable matter. It is difficult, however, to determine in what manner it has been formed, or by what operations the vegetable matter from which it is originated, has been so far modified as to have assumed the properties under which it exists. The discussion of this subject is intimately connected with geological speculation; for the opinion which is adopted must be in conformity to the



general theory which is held with regard to the structure of the globe. It is accordingly maintained in one geological system, that it derives its origin from vegetable matter which has been exposed under compression to subterranean heat; while in another it is supposed to have been formed from vegetable matter suffering slow decomposition under water, or at least in a state of humidity, by which its oxygen and hydrogen had been in a great measure withdrawn, and its carbonaceous base left predominant. The merits of either theory must rest on those of the more general systems with which they are connected. It has even been doubted whether the common or black coal is of vegetable origin; and Mr Jameson maintains the opinion, that, like blind coal, it is an original mineral deposit.

The bituminous part of coal is separated from the carbonaceous part by the application of heat. We perceive this separation in its combustion in a common fire; the coal, when first kindled, swelling and softening, exhaling a kind of bitumen, and burning with smoke and light; while, after a certain period, these appearances cease, and it burns only with a red light. The separation is effected more completely by the application of heat in close vessels; the bitumen is melted out, and there are disengaged ammonia, partly in the state of carbonate, with empyreumatic oil, and the coal gas, a variety of carburetted hydrogen, approaching to olefiant gas, which burns with a bright flame; it is often mixed with carbonic acid, and sulphuretted hydrogen; the carbonaceous matter is in a great measure left, forming Coak.

This decomposition of coal by heat is carried on on a large scale, with a view to collect the products; the gas being used to afford an artificial light, clear, steady, easily regulated and economical; the bituminous matter, or



mineral tar, being applied to the uses for which vegetable tar and pitch are employed, and the coaked coal being used in the smelting of metallic ores, and for other purposes.

SECT. III.—*Of Inflammable Minerals, in which Hydrogen predominates.*

To this genus belong principally the liquid bitumens.

Of these NAPHTHA is the purest. It is very light, of a pale yellow-green colour, transparent, thin, and liquid, odoriferous, volatile, and inflammable, and in burning is entirely consumed, emitting a smoke more or less dense. PETROLEUM, or mineral tar, is semi-liquid, often of a thicker consistence, tenacious, semi-transparent, of a reddish-brown colour, and fetid odour. MINERAL PITCH, or Maltha, is solid, but soft, has a degree of tenacity, and a strong bituminous smell. Its colour is black, its lustre highly resinous. It is sometimes elastic, forming what has been named the Elastic Bitumen. ASPHALTUM is the last of the series, and forms the connection with pitch coal. It is of a black colour, and resinous lustre; its fracture conchoidal; it is light, and has a bituminous smell when rubbed or heated. It melts easily, takes fire, and burns without leaving any ashes. Through all these substances there is a perfect gradation; naphtha, by inspissation, becoming petroleum, and this, by the same operation, passing into asphaltum; and even the different specimens of these are frequently found in the same situation. They also agree in their chemical characters, are inflammable, insoluble in water and in alcohol, but combine with fixed and essential oils, and are partially soluble in ether.



FOSSIL RESIN occurs in beds of clay in round masses of a brownish colour, semi-transparent, with resinous lustre: it is fusible and inflammable. <sup>Retin-</sup>RESIN-ASPHALT is another substance of resinous lustre and appearance, but opaque; it softens when heated, gives a fragrant odour, and burns with bright flame. It is a compound of resin and asphaltum, and is found in brown coal.

AMBER is placed among the bitumens. It is of a yellow colour, pale or deep, with a shining lustre, and a transparency more or less perfect; its fracture is conchoidal; it is brittle, and has a specific gravity of 1.08. It is inodorous except when heated; when rubbed, it becomes strongly electrical. It occurs in fragments, or in large masses; it is found in layers of bituminated wood, or buried in sand on the sea-shore. No satisfactory theory has been given of its origin. It often contains perfect organic remains, as of flies,—a proof of its having been once fluid.

Water exerts no action on amber. Alcohol acts on it weakly, acquiring some degree of colour and tenacity. The alkalis dissolve it, forming a kind of soap. The acids decompose it, changing it into a species of resin, and ultimately into tannin. It is not dissolved by the expressed or essential oils; but it becomes soluble by being roasted gently. Solutions of this kind are used as varnishes.

When amber is exposed to heat in close vessels, it softens and swells; and with a portion of empyreumatic oil, a quantity of an acidulous liquor passes over; this is succeeded by a concrete acid, which condenses in flakes or needles, which is obtained from no other substance, and is different from all the other acids. When heated in contact with the air, it inflames, burns with much smoke, and with a strong bituminous smell, and leaves little residue.

The acid obtained by the same decomposition, the Succinic Acid, is possessed of properties which sufficiently dis-



tinguish it. When freed from the oily matter which adheres to it at its first sublimation, it is white, and crystallizes in four-sided rhomboidal plates; its taste is sour, and it reddens infusion of litmus; it is soluble in 24 parts of water at 60, and is also soluble in alcohol. It is volatile and inflammable. Like the other vegetable acids, it consists of carbon, oxygen, and hydrogen. According to Berzelius and Thomson, the proportions are four atoms of carbon, 24, three of oxygen, 24, and two of hydrogen, 2; its equivalent is therefore 50. This, however, is exactly the constitution of acetic acid, a circumstance which throws doubt on the analysis. It has been indeed supposed, that bodies may combine in the same proportions, and yet form different compounds from a different arrangement of the atoms; and the instances of the varieties of olefiant gas, (vol. i. p. 616,) and of the fulminic and cyanic acids, have been adduced in support of this hypothesis. The differences in the properties of the varieties of olefiant gas are however obviously attributable to the difference of condensation; and with regard to the fulminic acid, it is not certain that it can exist insulated, and without a metallic ingredient. These examples, then prove little in favour of the hypothesis, and it possesses, in other respects, little probability.

Succinic acid combines with the alkalis, earths, and metallic oxides, but these combinations present no important results. The succinate of iron is insoluble; hence this acid is employed in the state of succinate of ammonia as a test of iron, and as a re-agent by which substances may be freed from it. It is also used to discriminate between magnesia and alumina, the succinate of magnesia being soluble, while that of alumina is insoluble, and is therefore precipitated.

MELLITE, or Honey-stone, is connected with the bitu-



mens. It is a rare mineral, resembling amber: it is of a honey-yellow colour; is more or less transparent; its lustre is vitreous or resinous; its surface smooth; its fracture conchoidal; it occurs crystallized in octaedrons, dodecaedrons, or four-sided prisms acuminated by four planes. Klaproth found it to consist of a peculiar acid, hence named Mellitic Acid, united with alumina. The acid may be extracted by water, and by evaporation, and the action of alcohol, to separate a portion of earthy matter, and may be obtained crystallized in prisms, having a yellow tinge, and a slight acid taste, accompanied with bitterness. It is sparingly soluble in water. Exposed to heat it swells, emits a dense smoke, and is charred; it is analogous in constitution to the vegetable acids, bearing considerable resemblance in its characters, and the salts which it forms, to the oxalic acid.

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#### CHAP. V.—OF MINERAL WATERS.

**M**INERAL waters, containing various ingredients, cannot be placed under any of the established classes of chemical agents; but they may be considered after the metallic and earthy fossils, as it is from these that they derive in general their qualities. Though all waters, that which descends in rain excepted, may be styled Mineral, as they contain more or less of saline and earthy matter, yet the term is restricted to those in which the quantity is such as gives the water taste or smell, renders it capable of producing peculiar effects on the animal system, or communicates distinguishing chemical properties.

The substances found in mineral waters are numerous. The most common are, carbonic acid; sulphuretted hy-



drogen; carbonates, sulphates, and muriates\* of soda, lime, and magnesia; and carbonate and sulphate of iron. Those of more rare occurrence are, sulphurous acid, nitrogen gas, sulphate of alumina, muriate of manganese, siliceous earth, fluoric acid, lithina, strontites, potash, and hydriodic acid.

From the predominance of certain of these ingredients, mineral waters may be characterized. They have thus been divided into four classes: 1st, Those in which carbonic acid is predominant, hence termed Carbonated Waters. 2d, The sulphureous, the principal ingredient of which is sulphuretted hydrogen. 3d, The chalybeate, or those having iron for their chief constituent; and, 4th, The saline, in which various neutral salts are dissolved. This affords the most convenient arrangement, under which they may be considered.

I. CARBONATED WATERS. — Mineral waters of this class have a pungent acidulous taste, and sparkle when poured into a glass: they become vapid from exposure to the air, or to a moderate heat, from the escape

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\* These when dry are, according to the present views of the nature of muriatic acid, not salts but metallic chlorides: the term of "muriates" is, however, correct, when applied to them in their state of solution in mineral waters. The estimated proportions of these substances given in this chapter, are to be understood to refer to them in the dry state, when they are probably metallic chlorides. If it is wished to ascertain the equivalent quantities of what are at present called muriates, namely, compounds of muriatic acid gas with oxidated bases, it is merely necessary to add an atom of water to the equivalent number of the dry chloride; thus, the equivalent of chloride of calcium is 56; when it is dissolved in water, it combines with an atom of that liquid equal to 9, and forms an equivalent of muriate of lime equal to 65.



of the carbonic acid gas. The chemical tests to discover the acid are infusion of litmus and lime-water; the first receiving from the mineral water an evanescent redness, the second producing a milkiness or precipitation which disappears when an excess of the mineral water is added, the carbonic acid rendering soluble the carbonate of lime, to which the turbid appearance is owing. The transparency is equally restored by dropping into the liquid a little muriatic or nitric acid. By the evanescent redness given to litmus, carbonic acid is distinguished from any other free acid that might be present; and by the transparency being restored by these re-agents, the fallacy is guarded against, that might arise from the precipitation of the lime by any sulphate in the water. The quantity of this acid gas may be ascertained by exposing the water to heat in a retort, collecting the gas disengaged in a jar over mercury, and introducing a solution of potash, by which the carbonic acid is absorbed. Sulphurous acid gas is sometimes, but very seldom, present in mineral waters: it is discovered by its smell, by giving a permanent red colour to a solution of litmus, and by rendering colourless an infusion of roses. Its quantity is estimated by expelling it, exposing the gas to a solution of potash, and obtaining the sulphite of potash; or by adding to it sulphuretted hydrogen gas as long as any diminution of volume is produced, these two gases, by their mutual action, being converted into water and sulphuric acid, and being therefore entirely condensed.

II. SULPHUREOUS WATERS.—The sulphuretted hydrogen, existing in these waters, is discovered by its smell, by the deposition of sulphur from them on exposure to the air, or on the addition of nitrous acid, by blackening silver or mercury immersed in it, and affording a dark-



coloured precipitate with acetate of lead. It may be expelled from the water by boiling, and its quantity estimated by passing it through a solution of acetate of lead, and weighing the sulphuret which is precipitated. Or the method of Kirwan may be employed, in which a quantity of the water is inclosed with atmospheric air in a jar inverted in water: nitrous gas is passed through the water, so as to combine with the oxygen of the atmospheric air; nitrous acid is formed, and this, being absorbed by the water, decomposes the sulphuretted hydrogen; the quantity may be inferred from the quantity of sulphur precipitated, and collected on a filtre, 34 grains of sulphur being held equivalent to 100 cubic inches of sulphuretted hydrogen gas. When sulphuretted hydrogen and carbonic acid gases exist together in the mineral water, the elastic fluid obtained from the water by heat is exposed in a tube to nitrous acid, by which the sulphuretted hydrogen is immediately absorbed and decomposed.

Nitrogen gas is contained in some mineral waters. It may be expelled by heat, and may be distinguished by its not being absorbed by lime water or solution of potash.

After the gaseous substances in carbonated and sulphureous waters have been expelled and examined, the solid ingredients are to be ascertained by the same methods by which they are obtained from the next two classes of Chalybeate and Saline Waters.

CHALYBEATE WATERS contain protoxide of iron as their most active ingredient, generally with portions of the salts met with in waters. The iron is retained in solution usually by an excess of carbonic acid, sometimes, but more rarely, by sulphuric acid. These waters have a styptic taste, and unless when very weak, deposite a pellicle or sediment of hydrated peroxide of iron on expo-



sure to the air. The tests for iron are tannin, generally conjoined with gallic acid as in the infusion of galls, and prussiate of potash: the former of these strikes a purple colour, the other gives rise to a blue precipitate. The latter is liable to fallacy, principally from the iron which exists in its composition, and which is liable to be evolved by an acid, so as to give rise to the blue precipitate. The former is not liable to this or any other important fallacy, and is a test of great delicacy. If 3 grains of crystallized sulphate of iron, which contain about 1-24th of a grain of the metal, be dissolved in  $5\frac{1}{2}$  English pints of water, the solution strikes a purple colour in five minutes with one drop of the tincture; hence it discovers in water a quantity of iron, amounting only to 1 in 48789 parts. A sensible tinge is even said to be produced with one grain of sulphate dissolved in 15 gallons of water. The colour is liable to be varied by the action of various salts; alkaline and earthy carbonates rendering it violet, neutral alkaline salts deepening the purple tint, and sulphate of lime rendering the precipitate at first whitish, and afterwards black. Mr Phillips has shown, that carbonate of lime has a singular effect on the production of the colour. If the iron be in small quantity, and at a high state of oxidation, the colour does not appear; while, if it is at a low state of oxidation, the purple tint is even heightened. And he has thus been enabled to explain a fact before inexplicable, and which had given rise to various opinions with regard to the waters of Bath,—that when taken immediately from the spring, and while hot, they give indications of a very small quantity of iron, by the test of galls, while, when they have cooled, so that the protoxide of iron which existed in them has become peroxide, they appear from the same test to contain none, though no iron is deposited during the cooling. By applying this



test before and after ebullition of the mineral water, we discover whether the oxide of iron has been dissolved by carbonic acid, or sulphuric acid, as if the former has been the solvent, being expelled during the boiling, the oxide is precipitated, so that the liquor, after filtration, when cold, either does not suffer the change of colour, or the tint is much less deep. To estimate the quantity of iron in a water, neither of these tests is of much value. The triple prussiate already contains iron, which it is difficult to make allowance for, and the precipitate from galls takes a very long time to subside. The quantity of oxide may be in some measure determined by its precipitation from exposure to the air and ebullition; or it may be precipitated by succinate of soda, and the precipitate, calcined at a red heat with a little carbonaceous matter, gives the quantity of peroxide of iron. Benzoate of soda may be substituted as more economical. These methods are likewise imperfect; they succeed only with a concentrated solution, and alumina, if present, is liable to be thrown down. What I have found, on the whole, the best mode of determining the weight of iron, is to evaporate the water as far as can be done without precipitation, adding previously a minute quantity of muriatic acid to retain the protoxide dissolved, then to add to the liquor evaporated a minute quantity of ammonia, so as to produce the slightest possible alkaline excess; the oxide of iron, if in considerable quantity, will be immediately thrown down; if it is in very small proportion, it will separate in a day or two. The precipitate washed and calcined at a red heat is the pure peroxide, 100 parts of which contain 70 parts of metallic iron, and are equivalent to 90 of the protoxide. Care must be taken in using this method to avoid adding an excess of ammonia, otherwise it may throw down alumina or magnesia if they are present. If this should hap-



pen, they may be abstracted from the oxide by a little distilled vinegar.

Oxide of manganese has been found in a few mineral springs along with oxide of iron. It is detected by prussiate of potash giving a white, and hydro-sulphuret of ammonia a black precipitate, and by carbonate of ammonia or soda throwing down a precipitate, which becomes black when laid on a plate of iron at a red heat.

SALINE WATERS form the last class. There are two objects in their analysis,—first, to discover their presence, and, secondly, to estimate their quantities.

The mineral acids, when not combined with any base, or in excess, are discovered by the water giving a permanent red colour to vegetable infusions, as those of litmus, violet, or blue cabbage. These acids uncombined, are, however, very seldom found.

The neutral and earthy salts are the chief ingredients of mineral waters. We have to ascertain the acids they contain, and the bases with which these are united; and for this purpose it is in general necessary to reduce the volume of the water by evaporation, to render more sensible the operation of the re-agents by which they are detected; taking care only, when the evaporation is executed with this view, not to carry it so far as to give rise to the separation of any of the solid ingredients.

Sulphuric acid, in combination with the alkalis or earths, is detected by muriate of barytes, acetate of lead, and nitrate of mercury, all of these producing an immediate precipitation. The first is at once the most delicate and most accurate, and the others therefore may be regarded as superfluous. Its delicacy is such that it discovers a quantity of sulphuric acid not greater than 1 part in 190,250 parts of water. The only fallacy to which it is liable, is that of affording a precipitate from the presence of an al-



kaline or earthy carbonate; this is obviated by adding previously to the water, a small quantity of pure nitric or muriatic acid, or by the turbid appearance, after it has been produced, disappearing, if it has arisen from this, on the addition of few drops of either of these acids.

Muriatic acid is detected by nitrate of silver; the chloride of silver which is formed being, from its insolubility, instantly precipitated, and giving rise to a bluish turbid appearance. The delicacy of this as a re-agent is extremely great; one grain of sea-salt dissolved in 42,250 grains, or rather more than 5 pounds of water, produces white streaks on the addition of a few drops of the nitrate. It is liable to fallacy, however, from a precipitate being likewise produced by it from the presence either of any carbonate or any sulphate. The operation of the former is obviated by the previous addition of a few drops of pure nitric acid, which decomposes the carbonate, and expels the carbonic acid; to avoid the latter, it is necessary to decompose any sulphate by the addition of nitrate of barytes.

Carbonic acid, in combination with the alkalis or earths, may be discovered by the effervescence produced by the addition of sulphuric acid, when concentration has been produced by evaporation, and by muriate of barytes forming a precipitate soluble with effervescence in nitric or muriatic acid. The alkaline carbonates are distinguished by their power of changing the vegetable colours; the earthy and metallic carbonates, by being precipitated when the water is partly evaporated. The earthy carbonates, when in considerable quantity, are found also to restore the blue tint of litmus reddened by vinegar, the earth neutralizing the acetic acid, when the natural tint of the litmus appears.

The earths with which they are principally combined



are lime, magnesia, and alumina. They are all precipitated by carbonate of soda, which is thus a delicate test of the presence of earthy salts. The quantities of the different earths may be ascertained by using the following re-agents.

Lime is *immediately* precipitated from all its combinations by oxalic acid. Some of the mineral acids, however, either decompose this acid, or hold dissolved the precipitate it forms with the lime, and hence, if disengaged by the decomposition, may have this effect. This fallacy is guarded against by using, not the pure acid, but oxalate of potash or ammonia, the alkali neutralizing the acid disengaged from the lime; oxalic acid produces a precipitate likewise with magnesia, but this takes place very slowly, even when the magnesian salt is in large quantity, while with lime it is immediate. In using the test of oxalate of ammonia, it is necessary that the water should be previously freed from any salts of iron which may have existed in it, as Dr Marcet has shewn that this re-agent precipitates iron. Sulphuric acid has also been used as a test to discover lime; but it is one of much less delicacy. Fluuate of ammonia is a very delicate test, but it is one difficult to prepare.

Ammonia and lime-water are the tests of Magnesia, the former precipitating it partially, the latter entirely. In order that the lime may be an accurate test, it is necessary to remove any carbonic acid which may exist in the water, by previously adding nitric acid; and any sulphuric acid, by muriate of barytes. Another source of fallacy more important, arises from alumina being precipitated by these re-agents, as well as magnesia. The nature of the precipitate may be discovered by dissolving it in nitric or muriatic acid, and again precipitating the solution by carbonate of potash. If this dried precipitate be subjected to



the action of diluted sulphuric or muriatic acid, it will be immediately dissolved if the earth be magnesia, while, if it be alumina, it will dissolve slowly. Or the precipitate may be boiled in a solution of potash; if it be alumina it is dissolved, while magnesia remains undissolved. Succinate of ammonia too precipitates alumina, but not magnesia. But the best mode of discovering magnesia is by the formation of its triple phosphate with ammonia. This may be employed by the method of Dr Wollaston, of adding to a solution containing any magnesian salt, carbonate of ammonia; no effect appears, but, on adding phosphate of soda, precipitation takes place. It has been remarked by Mr R. Phillips, that some fallacy may arise in employing the test in this form, from the carbonate of lime which sesqui-carbonate of ammonia generally contains, and which may occasion a precipitation of phosphate of lime. Hence he prefers the use of lime-water to precipitate the magnesia when the water contains no alumina, nor any alkaline carbonate; any oxide of iron being also previously separated. With these precautions, he states it to be a very delicate re-agent, precipitating less than 1-12th of a grain of magnesia in a pint of water. A variation of Dr Wollaston's test, is to use, instead of carbonate of ammonia and phosphate of soda, sub-phosphate of ammonia; and if lime has been previously removed from the water, it is not liable to any objection.

The alkalis, when in a state of combination, cannot be discovered by any striking tests, but their presence is inferred when acids are discovered in a mineral water which are not free, and which, at the same time, from the application of tests, do not appear to be combined with earthy or metallic bases. Soda is the alkali generally present. The peculiar salts which it and potash form with the different acids serve to distinguish them. With oxalic acid



soda forms a salt sparingly soluble; while potash forms, with the same acid, a salt easily dissolved. With tartaric acid, on the contrary, soda forms a soluble salt; while with potash an acidulous tartrate is formed, of comparatively sparing solubility. Muriate of platina affords a test still more delicate, giving a precipitate with the salts of potash, but not with those of soda.

Siliceous earth is contained in some waters, not combined, however, with any acid. A portion of alkali, likewise, generally exists in such water; but this is either in the state of carbonate, or in such small quantity that it can scarcely be considered as the solvent of the silex. This earth may be discovered by evaporating the water, and adding to the solid residuum nitric or muriatic acid; the silex will remain undissolved; and its nature may be still more clearly proved by fusing it with the blowpipe, with either of the fixed alkalis.

Besides the methods of discovering the saline ingredients in mineral waters by re-agents which indicate their principles, they may, by certain methods, be obtained in their entire state, and their quantities determined.

Evaporation is employed with this view, different substances being successively obtained as the evaporation is carried to a greater or less extent. Thus, the carbonates of lime and magnesia are usually first precipitated, afterwards sulphate of lime falls down: if after these precipitations the liquor be drawn off and allowed to cool, the alkaline neutral salts and the sulphate of magnesia crystallize, while muriate of magnesia and muriate of lime, if present, will remain, forming an uncrystallizable residue.

Alcohol facilitates the analysis by a similar operation. When added to the water brought to a certain state of concentration, it throws down first sulphate of lime, afterwards carbonate of lime and carbonate of magnesia; and



if added in larger quantity, or after a renewed evaporation, it either precipitates or causes to crystallize sulphate of magnesia and sulphate of soda, while any muriates remain dissolved. Advantage, too, is taken of its power of dissolving some salts with more facility than others: thus the muriates of magnesia, lime, alumina, and iron, are much more soluble in alcohol than the carbonates and sulphates of these bases, and by the action of successive portions of alcohol may be separated from them. It not unfrequently happens, however, as I have shown, in the analysis of sea-water, that the alcohol does not act simply as a solvent, but by its solvent power changes the state of combination of the elements of the water, and gives rise to the formation of new products.

The precipitates obtained by employing these re-agents should be separated by means of a filter of unsized paper, washed by pouring distilled water upon them, and then dried by a greater or less degree of heat, and weighed. Dr Thomson has stated an objection to the use of filtering paper, that he has always found it to contain a portion of sulphate of lime. When allowance, however, is made for this, and the paper carefully washed with distilled water before using it, it affords the most convenient method of collecting a precipitate.

It is by these methods of evaporation and precipitation, that the ingredients of Mineral Waters have been determined. By the use of re-agents, their principles are discovered, and even the quantities of these may be estimated. The quantity, for example, of sulphuric acid may be ascertained from the weight of the precipitate formed by adding muriate of barytes, the proportion of sulphuric acid which a given weight of the sulphate of barytes formed, when dry, contains, being known: the quantity of mu-



riatic acid may be inferred from the weight of the precipitate of chloride of silver formed by adding nitrate of silver; that of carbonic acid, from the weight of the precipitate of carbonate of barytes or of lime formed by the addition of water of barytes or lime; that of lime from the weight of the oxalate of lime precipitated by oxalate of potash; and in a similar manner, the weights of other substances that can be precipitated by re-agents in new states of combination may be determined.

The substances obtained by evaporation of a mineral water have always been regarded as the actual ingredients which had existed in it. Thus, when by evaporation sulphate of lime, carbonate of lime, muriate of soda, and other salts were precipitated or crystallized, it was inferred that these were the salts which had been in a state of solution in the water. And when the method of re-agents has been employed, it has been the constant practice to refer to the products of evaporation as the true constituents, and to arrange the acids, alkalis, and earths obtained, in conformity to this opinion.

Some circumstances led me to doubt the justness of this view. In evaporation, or any analogous analytic operation, it is possible that the state of combination in saline compounds may be changed by the concentration, and that thus the binary compounds obtained may often be very different from the original ingredients.

Thus, suppose that a mineral water affords by evaporation muriate of soda, muriate of lime, and sulphate of lime, these may not have been the salts which existed previous to the evaporation: the solution may have contained the sulphuric acid in the state of sulphate of soda, and when concentrated, this salt might act on the muriate of lime, and form, by double affinity, muriate of soda and



sulphate of lime \*. In like manner, if carbonate of lime and muriate of soda be obtained by evaporation, the real ingredients may be carbonate of soda and muriate of lime : if carbonate of magnesia and muriate of soda are obtained, they may be carbonate of soda and muriate of magnesia : even sulphate of magnesia may be formed from the action of sulphate of soda on muriate of magnesia ; and thus the apparent composition inferred from the products of the analysis may be very different from that which truly exists.

Different reasons render these the more probable conclusions. The actually obtaining certain binary compounds, is no proof of their prior existence, for the circumstances under which they are obtained may equally cause their formation. On the other hand, if they exist in the reverse mode of combination, this may be, and indeed often must be, changed by evaporation. If muriate of lime and sulphate of soda, for example, exist in a mineral water, it is demonstrable, that by evaporation they must be obtained not in this state, but as muriate of soda and sulphate of lime. The principle, too, is most probable, *a priori*, that the most soluble compounds will be those which exist in solution. In various instances of mineral waters, the less soluble compounds, carbonate of lime, carbonate of magnesia, and sulphate of lime, are obtained by evaporation in proportions much larger than those in which they could exist in the water from their known solubility, and frequently they are separated in an early period of the evaporation, and their production afterwards ceases ; circumstances proving that they are products of decomposition. And, lastly, the actual ingredients

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\* It was the analysis of a mineral water affording these ingredients, that of Dunblane, that first suggested to me this view.



often accord best with these views; muriate of soda, for example, being almost always a product where sulphate or carbonate of lime exists, while sulphate or carbonate of soda is never obtained by evaporation where muriate of lime is present.

The importance of this view is apparent when it is considered, that these insoluble compounds, so often indicated as the ingredients, are comparatively inert, while the others are of considerable activity: accordingly, it presents, in many cases, a more active composition, and of course affords a more satisfactory solution of the medicinal powers of mineral waters, than is obtained in the opposite opinion. Seltzer water, for example, is one of great efficacy: on the old doctrine, its ingredients, along with an excess of carbonic acid, are carbonates of lime and magnesia, muriate of soda, and a small portion of carbonate of soda, exhibiting, therefore, little apparent power. But when considered in the reverse view, as composed of a large proportion of carbonate of soda, with muriate of magnesia and muriate of lime, we are enabled to account for the great activity it exerts. No probable explanation has ever been given of the efficacy of the celebrated Bath Water; from its analysis, its chief ingredient being sulphate of lime, a substance inert, with a little muriate and sulphate of soda, minute quantities of carbonate of lime and siliceous earth, and a very inconsiderable impregnation of iron. But when muriate of lime is regarded as its principal ingredient, we assign to it an adequate degree of power.

In the analysis of mineral waters, then, it is not sufficient to discern merely the ingredients which are obtained; they must often be different from the real composition; and it is necessary that this should, as far as possible, be inferred. The general principle which has appear-



ed to me most probable, on the supposition that binary combinations exist in a saline solution, is, that the most soluble compounds among the existing elements will be formed, or that if we discover and estimate the elements of a mineral water, namely, the acids, alkalis, and earths, which it contains, and arrange these into the most soluble salts which these elements can form, we shall obtain the probable composition of that water.

The opinion now stated, leads also to views of the modes of analysis of Mineral Waters, different from what have been hitherto adopted. From its having always been considered necessary to infer the composition from the actual ingredients by evaporation, the more accurate method of discovering it by re-agents has been only occasionally employed, and as subordinate to the other. It must be apparent, however, that the one mode does not give the composition with more certainty than the other; the products of evaporation are not necessarily the compounds which existed in solution; what these are, must be inferred from some other principle; and under this point of view, a knowledge of their elements affords information equally precise with that of the compounds themselves; and this mode of analysis by re-agents is more simple, and liable to fewer errors, nothing being more difficult than to produce the perfect separation of salts by evaporation, while the discovery of their acids and their bases from the application of re-agents is more easily attained.

On this principle I have proposed a General Formula, for the analysis of mineral waters, which may be employed, instead of the great diversity of methods which have been in use, often complicated, and always adapted to particular cases. The following is an outline of it.

The Four classes of Carbonated, Sulphureous, Chalybeate, and Saline waters have been established. All of



them, however, may be reduced in analysis to the Saline. From the carbonated waters the excess of carbonic acid is expelled by heat, and its quantity is estimated: from sulphureous waters, the sulphuretted hydrogen is in like manner disengaged; from the chalybeate waters, iron is obtained by its appropriate tests; and in all these cases the water remains with any saline impregnation, and of course is essentially the same with a water originally saline.

The salts usually contained in mineral waters are carbonates, sulphates, and muriates of lime, of magnesia, and of soda. Suppose a general knowledge of its ingredients to be gained by the use of re-agents and by evaporation; and suppose, for illustration, that all these are present, the following are the successive steps to be employed.

Reduce the water by evaporation as far as can be done without occasioning any sensible precipitation or crystallization. This concentration favours the operation of re-agents.

Add to the liquor thus concentrated a saturated solution of muriate of barytes as long as any precipitation is produced, taking care to avoid adding an excess. If the precipitate effervesce with muriatic acid, and is entirely dissolved, it is carbonate of barytes, 100 grains of which, when dried, indicate 22 of CARBONIC ACID. If it do not effervesce, it is sulphate of barytes, 100 grains of which dried at a low red heat are equivalent to 33.9 of SULPHURIC ACID. If it effervesce, and is partially dissolved, it consists both of carbonate and sulphate, to ascertain the proportions of which let the precipitate be dried and weighed; then submitted to the action of dilute muriatic acid, and again washed, and dried at a low red heat; the weight of the residue will give the quantity of sulphate, and the loss of weight the quantity of carbonate of barytes.



The Carbonic and Sulphuric acids are thus removed and estimated, and the whole salts in the water are converted into muriates. It remains to discover and estimate their bases, and to find the quantity of muriatic acid originally contained.

Add to the clear liquor a saturated solution of oxalate of ammonia, as long as any precipitation takes place. The lime is thus precipitated in the state of oxalate, which being calcined at a low red heat, is converted into carbonate; this is to be converted into sulphate by the addition of sulphuric acid; and this being exposed to a red heat, 100 grains of it are equivalent to nearly 41.2 of LIME.

The next step is to estimate the MAGNESIA. To the residual liquor add a portion of carbonate of ammonia, and drop in pure phosphoric acid, or phosphate of ammonia, as long as any precipitation takes place, continuing always in the liquor a slight excess of ammonia. The triple phosphate of magnesia and ammonia is thrown down; and this being calcined at a red heat for an hour, is converted into phosphate of magnesia; 100 grains of the residue are equal to 41.6 of magnesia.

Evaporate the remaining liquor to dryness, and expose the dry matter to heat as long as any vapours exhale, raising it at the end to redness. The residue is muriate of soda, the weight of which gives the quantity of SODA, 100 grains being equivalent to 53.3.

The muriatic acid in the muriate of soda obtained, may be either greater or less than that originally contained. To discover the real quantity, combine in binary compounds, according to their known proportions, the bases indicated in the analysis, with the acids, (taking the quantity of muriatic acid in the muriate of soda obtained). Any excess or deficiency of muriatic acid will then appear; and the amount of the excess being subtracted from the quantity found in the muriate of soda, or the amount of



the deficit being added to that quantity, the real quantity of muriatic acid will be determined. Or it may be directly inferred, from the addition of nitrate of silver to a given portion of the water from which the sulphuric and carbonic acids have been abstracted by nitrate of barytes, 100 grains of the precipitate of muriate or chloride of silver being equivalent to 19.18 of real muriatic acid of the old theory, or to 24.66 of chlorine, or to 25.34 of muriatic acid gas \*.

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\* Instead of calculating from the proportions in 100 parts, which frequently involve fractional numbers, it may be easier and more accurate to calculate from the combining weights of the acids and bases. These are as follows: Sulphate of barytes thoroughly dried consists of one atom of sulphuric acid 40, and one of barytes 78, = 118. Carbonate of barytes is composed of one atom of acid, 22, and one of barytes, 78, = 100, the atomic weights in this instance coinciding with the proportions in 100 parts. Sulphate of lime consists of one atom of acid, 40, and one of lime, 28, = 68. Phosphate of magnesia is composed of one equivalent of acid, 28, and one of magnesia, 20, = 48. Muriate of soda of one of acid, 28, and one of soda, 32, = 60; or, on the new view, of one atom of chlorine, 36, and one of sodium, 24, = 60 when dry, and of one of muriatic acid, 37, and one of soda, 32, = 69 when in solution. Muriate of silver of one of oxide of silver, 118, and one of muriatic acid, 28, = 146; or, on the new view, of one atom of silver, 110, and one of chlorine, 36, = 146. These numbers may be employed in calculation in the usual manner by the rule of proportion. If, for example, 60 grains of phosphate of magnesia are obtained from a certain portion of a mineral water, the weight of magnesia in this quantity is obtained by the proportion  $48 : 20 :: 60 : 25$ , which is one that may be determined with more facility and accuracy, than the proportion of  $100 : 41.6 :: 60 : 24.96$ , in which the fractional parts give rise to an incorrect result. ED.



The analysis being thus completed, the quantities of acids and of bases may be represented separately, and this perhaps affords the only certain conclusion that can be drawn. The quantities of binary compounds may however be inferred from these, according to whatever composition shall appear to exist; they may either be inferred from the principle, that the compounds existing in solution are those which are most soluble, or in conformity to the actual products of evaporation. Or they may be stated in both modes, and thus the analysis is presented under every point of view.

Other substances which are of less common occurrence may be detected by particular methods. Silica will be discovered by the gelatinous consistence it gives on evaporation, and its remaining insoluble in acids, but soluble in alkalis. Alumina may be discovered by the water giving a precipitate with carbonate of ammonia, which is not soluble, or is only partially soluble in weak distilled vinegar, but is dissolved by boiling in a solution of potash; or by its precipitation, from the water sufficiently evaporated, by succinate of soda. Potash, when present, will remain at the end in the state of muriate of potash. Muriate of platina will detect its presence, and the muriate of potash may be separated by crystallization from the muriate of soda. Hydriodic acid, which has been discovered in some mineral waters, may be detected by evaporating to dryness, redissolving the soluble matter in a cold solution of starch, and adding a portion of sulphuric acid.

SEA-WATER may be regarded as a Saline Mineral Water, containing only a much larger portion than usual of saline matter. The proportion differs in different latitudes, according to the influence of evaporation. The water of the Atlantic, in the warmer latitudes, contains



about  $\frac{1}{24}$  of saline matter; that of our shores, abstracting from the influence of fresh water, contains about  $\frac{1}{30}$ .

Different methods of analysing sea-water have been employed, and they have produced variable and contradictory results. The consideration of these uncertainties led me to undertake the analysis of sea-water, and to conduct the results in reference to the principles already illustrated with regard to the state of combination in saline solutions, and the modifications produced by the usual analytic operations.

By the method of evaporation, separating the salts as they crystallized or were deposited, I found the products from a pint of sea-water, (taken from the Frith of Forth,) to be muriate of soda 184 grains, muriate of magnesia 21.5, sulphate of magnesia 12.8, sulphate of soda 2, sulphate of lime 7.3 = 227.6.

By employing the method of Lavoisier, of evaporating to dryness, and submitting the dry mass to the action of successive portions of alcohol of different degrees of strength, to separate the salts, I found the results to be from a pint, muriate of soda 182.1 grains, muriate of magnesia 25.9, sulphate of soda 7.5, sulphate of magnesia 5.9, sulphate of lime 7.1.

It is evident, from the diversity of results in these two methods, that the products depend in part on the analytic operations; nor could a better proof be adduced, that the substances obtained in such processes are not necessarily the real ingredients, for here they are different from the same solution, according to the method employed. The difference evidently arises from the operation of alcohol favouring the production of sulphate of soda; and this again may be ascribed to its action as a solvent. Muriate of soda and sulphate of magnesia are, on the whole, less soluble in water than sulphate of soda and muriate of magnesia; hence in evaporation, the influence



of cohesion determines their formation. But muriate of magnesia and sulphate of soda are, on the whole, more soluble in alcohol, especially when it is a little diluted; and, therefore, in submitting the dry mass from evaporation to its solvent action, their production is favoured.

Lastly, by employing the method of precipitation by re-agents, described in the preceding formula, I found that a pint contains, of sulphuric acid 14.4 grains, muriatic acid 97.7, soda 96.3, magnesia 14.8, lime 2.9 = 226.1 grains. This is perhaps the only certain statement that can be given, for there is no direct proof how these elements are combined. It may be supposed that they are in simultaneous union, without forming any binary compound.

Or the binary compounds may be conceived to be those obtained by evaporation. On this view, the proportions will be muriate of soda 180.5 grains, muriate of magnesia 23, sulphate of magnesia 15.5, sulphate of lime 7.1.

Or the elements may be combined, in conformity with the principle which has been suggested, that the most soluble salts will be those existing in solution. Sea-water will, on this view, contain in a pint,

Muriate of Soda,	-	-	159.3 grains.
Muriate of Magnesia,	-	-	35.5
Muriate of Lime,	-	-	5.7
Sulphate of Soda,	-	-	25.6

It can scarcely be doubted, but that the last view is just \*. The mode of analysis, too, by which these pro-

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\* Dr Murray found reason afterwards to conclude, that the water of the Frith of Forth, even though collected at a distance from any source of fresh water, contained a less proportion of saline matter than what exists in the ocean; the influence of the fresh



portions were obtained, is the most accurate. And hence the last table may be considered as exhibiting the highest approximation to the real composition of sea-water.

Besides these ingredients, potash has been discovered by Dr Wollaston in sea-water ; and it has been mentioned, that traces of hydriodic acid have also been detected in it. The new principle Brome also exists in it, in the state, it is supposed, of hydro-bromic acid.

The Water of the Dead Sea in Palestine, it has been long known, has a strong impregnation of saline matter ; its specific gravity is 1.211, and its taste is intensely bitter. From its analysis by Dr Marcet, it appears that 100 grains contain 3.92 of muriate of lime, 10.24 of muriate of magnesia, 10.36 of muriate of soda, and 0.054 of sulphate of lime.

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The ingenious view given by Dr Murray of the real nature of Mineral Waters, of which an outline has been given in the text, is now regarded by many chemical authorities as one highly probable. The idea that the salts obtained by evaporation of a mineral water may not, as has always been imagined, be the real ingredients that existed in it, but may be the products of decompositions which happen during the concentration, is, when suggested, one so obvious and probable, that no objection of any weight can be urged against it. And the conclusion drawn by Dr Murray, that the most soluble salts are those most likely to exist in a very dilute solution, and that hence we may infer the composition of a

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water from a large river, extending, it would appear, much farther down its estuary than could at all have been imagined. The proportion of saline matter in the water of the German ocean is hence probably a little larger than what is here stated, but there is no reason to suppose that the relative quantities of the salts are different. ED.



mineral water, by arranging its elements, as detected by analysis, into the most soluble compounds, gives a highly interesting and satisfactory view of the nature of saline solutions. The manner in which this conclusion is deduced in the original memoir of Dr Murray, (Philosophical Transactions of Edinburgh, vol. viii.) is the following :—

The fact seems to be clearly proved, however it may be explained or reconciled with the common opinions respecting chemical attraction, that a very powerful influence is exerted on attraction by the force of cohesion. So much is this the case, that, as Berthollet justly remarked, when a number of principles are mixed in a state of solution, so concentrated as to admit of the influence of the force of cohesion, we shall always find that the least soluble compounds will be formed. If, for instance, equivalent quantities of muriatic acid, sulphuric acid, soda and lime are mixed in solution, the force of cohesion will determine the formation of muriate of soda and sulphate of lime ; for these are the least soluble compounds. Such will be the consequence, then, in a solution, where cohesion is not greatly counteracted by the solvent power of the liquid ; but when this solvent power is increased, as by adding to its quantity, a force, the reverse of cohesion, is introduced, which will, therefore, produce a reverse effect. Or, as the power of cohesion determines the formation of muriate of soda and sulphate of lime ; so the opposite power of the solvent may, or rather *must*, determine the production of the more soluble compounds, muriate of lime and sulphate of soda. As in a concentrated medium, then, the least soluble salts are formed, so in a dilute medium the more soluble compounds will be established. The power of the solvent is exerted with greatest effect on those which are most soluble ; and hence, if the reverse combinations even existed, this power must, probably, change them, and establish the others. The simple rule thus follows, that in any fluid containing the elements of compound salts, when the quantity of fluid is large in proportion to the saline matter existing in it, the binary compounds established will be those which are most soluble in that fluid, and the reverse combinations will be produced only by its concentration favouring the influence of cohesion.



Besides the probability given to Dr Murray's opinion by this reasoning, there are a number of facts which may be stated as favourable to it. Thus, the fact which has been mentioned, that by varying the manner of performing the analysis, as by first accomplishing it by the method of evaporation, and afterwards by the action of alcohol, the salts obtained are different, and in different quantities, is directly adverse to the common notion, that these salts existed in the same state in the water, and did not act on each other in the concentration; for if this were the case, the products should always be the same, and in the same quantities. But when sea water, for instance, is evaporated to dryness, principally sulphate of magnesia and muriate of soda are procured, which are the salts least soluble in water that these acids and bases can form; whereas, when alcohol is employed, sulphate of soda and muriate of magnesia are the chief products, these being more soluble in alcohol than the former, and the solvent action of that fluid, therefore, determining their formation.

Another important fact mentioned by Dr Murray, is, that where the ingredients of a saline water are deposited during evaporation, this deposition does not begin and proceed regularly in proportion to the diminution in the quantity of the solvent, but takes place principally when the concentration has arrived at a certain point, then diminishes, and at length ceases altogether, before the last portions of the liquid have been evaporated, clearly proving that the substance is not merely deposited as an original ingredient would be, from deficiency of the solvent, but rather as a product of chemical re-action between compound salts, one or other of which is in limited quantity. In the evaporation of sea water, for example, sulphate of lime and muriate of soda are deposited after a certain degree of concentration; but the proportion of the former diminishes, till at length it ceases to be produced, and the residual *bittern* is altogether free from it. Had the sulphate of lime been merely in a state of solution, as if no other substance had been present, it would assuredly have been gradually precipitated, as the evaporation proceeded, even to the end; if, on the other hand, as Dr Murray supposes, it does not pre-exist in the liquid, but is derived from the action of muriate of lime on sulphate of soda or of



magnesia, the result is precisely that to be expected,—the mutual action must take place when a certain degree of concentration is attained, and when the muriate of lime is exhausted must cease.

It was also found by Dr Murray, in analysing a mineral water, that of Dunblane, which contains a considerable portion of muriate of lime, that when he added to it a quantity of sulphate of soda, though no precipitation happened, on evaporation sulphate of lime and muriate of soda were obtained, a result which likewise favours the opinion, that the salts are changed during the evaporation.

From several mineral waters, larger quantities of insoluble matter, as of sulphate of lime and carbonate of lime, are obtained by evaporation, than what can be redissolved in them, or than what, from the known degrees of solubility of these substances, can be supposed to have existed in solution in the water,—a fact quite irreconcilable with the common notion, and which can be explained only by supposing the elements to exist in the state of other and more soluble salts. Thus, in the instance of the Carlsbad waters, a portion of fluuate of lime was obtained from them by Berzelius by evaporation. This is a substance so insoluble, that it could in no degree be dissolved even in a much larger portion of water. Berzelius conceived that it might be retained in solution by carbonic acid; but, on making the experiment, this supposition was not verified. The waters contain a large quantity of carbonate of soda, with an excess of carbonic acid. He next, therefore, mixed the fluuate of lime with carbonate of soda in the same quantity of water, and saturated the mixture with carbonic acid; and it was then found, that a considerable portion of fluuate of lime was dissolved. Hence he infers, that in these waters bi-carbonate of soda is the solvent of the fluuate of lime,—a result which is unintelligible, if the salts are conceived to continue in the same state in which they were introduced, but which is at once explained, if we suppose them to be resolved by the action of the solvent into fluuate of soda, a soluble salt, and carbonate of lime, which will, as in many other waters, be preserved in solution by the excess of carbonic acid.

An experiment which I have performed seems even to afford stronger proof of the accuracy of my Father's views, and appears to me almost decisive in their favour. Of all the salts which he



inferred to exist together in mineral waters, the most directly incompatible, are *carbonate of soda* and *muriate of lime*; they require, indeed, to be very largely diluted, to prevent their decomposing each other. If, then, it can be shewn, that, in very dilute solutions, these salts remain as such, and do not form *muriate of soda* and *carbonate of lime*, the principle of inferring the most soluble salts to exist in dilute solutions may readily be admitted in other cases. Now, carbonate of soda may be detected, by its changing blue vegetable colours to green, from the predominance of its alkali; and, as this is a very delicate test, it will succeed even in very dilute solutions. Accordingly, I dissolved small quantities of muriate of lime and carbonate of soda in a large quantity of water, taking care that there should be an excess of muriate of lime; the solution was so dilute that no precipitation happened: according to the common notion, that incompatible salts cannot exist in solution together, muriate of soda and carbonate of lime would be formed; the latter being held dissolved only by the large quantity of water. If this happened, no effect would be produced on vegetable colours; for the alkali would be neutralized by the muriatic acid, and the lime being in such small quantity, and in union with carbonic acid, its weak alkaline power could not produce any perceptible effect. On Dr Murray's view, again, muriate of lime and carbonate of soda, being the most soluble salts, would exist together unchanged, and vegetable colours ought to be affected. Accordingly, when an infusion of blue cabbage was added, the colour was immediately changed to green, affording an unequivocal proof of the truth of the opinion, that salts, usually supposed to be incompatible, may exist together.

Another appearance presented in this experiment may be stated, in support of the principle on which Dr Murray accounted for the existence of incompatible salts in dilute solutions; the principle, namely, that as the force of cohesion tends to establish the formation of insoluble compounds, so the reverse power of the solvent determines the formation of soluble compounds. The appearance was one sufficiently common, that the carbonate of soda, when dropped into the solution of muriate of lime, caused at first a slight turbidness, which disappeared on agitation, and, after the solution



was thus complete, vegetable colours were changed to green : Now the turbid appearance arose from the formation of carbonate of lime, the quantity of water in which the carbonate of soda was at first diffused not being sufficient to prevent decomposition : According to the common opinion, the large quantity of water brought to act upon this carbonate of lime by the agitation merely dissolved it ; but in this case, how should the alkaline property be exhibited, for the muriate of soda which would be formed at the same time is a neutral salt ? The only explanation that can be given, is, that, as Dr Murray inferred, the power of the solvent reversed the combination ; or as the force of cohesion had at first determined the formation of muriate of soda and carbonate of lime, so the power of the solvent, when aided by its increased quantity, converted these into the more soluble salts, and thus re-established the compounds of muriate of lime and carbonate of soda. This important principle, it is obvious, may be applied to a number of facts relative to saline solutions.

Lastly, the medicinal powers of mineral waters, which, as is very well illustrated in the instances of the Bath and Seltzer waters, are quite inexplicable on the common view of their composition, receive, from Dr Murray's doctrine, so satisfactory an explanation, as to afford a powerful argument in favour of that doctrine. Substances so inert, as carbonates of lime and magnesia, sulphate of lime, or even muriate of soda, cannot be supposed capable of communicating virtues of any importance to mineral waters ; while it may easily be conceived that the active salts, sulphate and carbonate of soda, with muriates of lime, magnesia, and perhaps iron, may give rise to considerable medicinal power. " Certainly," says Dr Scudamore, " the mode of estimate, pointed out by Dr Murray, is admirably favourable to the consideration of a mineral water as a medical remedy. When, by means of the direct mode of analysis, a water yields sulphate of lime and muriate of soda, and not muriate of lime, the inference is drawn by Dr Murray, that these are in part the result of double decomposition, and that, to a certain extent, more or less, the elements of the salts existed in the water as sulphate of soda and muriate of lime. Hence the physician is led to very different and important conclusions on the



“ subject of the water as a medicine, the muriate of lime being a  
“ valuable medicinal agent, the sulphate of lime not entitled to  
“ any such praise, while the sulphate of soda, however small in  
“ quantity, lends some useful aid.” It has been indeed doubted  
by some, whether the supposed beneficial effects from the use of  
mineral waters, may not rather be attributed to the mere dilution,  
and to other circumstances, as pure air, exercise, &c. rather than  
to their saline impregnation. This opinion seems to have arisen  
from the inert products of analysis being supposed to constitute the  
saline impregnation ; but when the constituents, as inferred on Dr  
Murray’s principle, are found to be active salts, greater influence  
must be allowed to them. The instance of the Tunbridge water,  
the most celebrated chalybeate in England, clearly proves, that an  
active medicine, even in a state of great dilution, may produce its  
peculiar effects. The quantity of oxide of iron in that water is less  
than two grains in a gallon, or one-eighth of a grain in the usual dose  
of half a pint ; yet this slight impregnation is sufficient to give the  
decided chalybeate taste, and to produce the medicinal effects which  
iron is known to occasion. In like manner, the soluble muriates of  
lime, magnesia, and soda, with the sulphate and carbonate of soda,  
though present in quantities far below the common doses in which  
they are given, yet, aided by the perfect state of solution in which  
they exist, by which they act in their full intensity on the whole  
surface of the stomach, and are probably, as Dr Murray suggests,  
received into the circulation, exert distinct and important me-  
dicinal powers. Thus, it has been remarked by Dr Scudamore,  
in his late valuable work, in which analyses are given of the prin-  
cipal mineral springs in England, in conformity with Dr Murray’s  
view, that those waters which contain the largest proportion of the  
soluble muriates are most stimulant and alterative. It even not  
unfrequently happens, that precautions are requisite to prevent in-  
jurious consequences from their use. The Bath waters, for instance,  
sometimes produce, with gouty patients, a paroxysm of gout, an ef-  
fect which Dr Scudamore ascribes wholly to the stimulating powers  
of the muriates ; and in the use of other waters, as that of Chelten-  
ham, from the same cause, a previous course of aperient medicines  
is recommended, that the habit may be freed from every material



symptom of excitement and visceral obstruction. The very different powers of different mineral springs likewise afford a proof that these depend upon the salts they contain. In attributing much of their virtues to the presence of muriate of lime, Dr Murray's view coincides also with the known utility of that salt in various diseases, particularly in scrofula,—a disorder which derives peculiar advantage from the use of saline waters, and in which the muriate of lime alone has been frequently administered with considerable benefit, and would probably be still more useful, if given in a state of very dilute solution, similar to that in which it is taken in these waters. In short, though the beneficial effects of mineral waters may partly be ascribed to the influence of concomitant circumstances, yet the different powers of different springs, their stimulating and aperient qualities, and still more certainly the precautions necessary to counteract their too great activity, prove that their virtues, in a great measure, depend on the saline ingredients which they contain ; and these ingredients can be supposed to be efficacious only when arranged on my Father's principle.

Some objections have been made to the opinions which have been illustrated, which I may here notice. They appear to me to have arisen from a partial view of the subject, and may be without difficulty answered.

The following remarks have been made by Mr R. Phillips : “ I cannot admit the position laid down by the late Dr Murray, that when certain acids and alkaline bases are mixed together in solution, such salts are most likely to be formed as are most soluble in water. If I put together certain quantities of sulphate of soda and muriate of lime, precipitation takes place, because sulphate of lime is formed ; but is it likely, that, as this theory supposes, the whole of the sulphate formed is thrown down ? Indeed, if I understand Dr Murray's position, it amounts to this, that supposing I mix together sufficient quantities of muriate of lime and sulphate of soda, to form one hundred parts of sulphate of lime, that sulphate of lime will only be formed if there be not water enough to hold it in solution ; but this would seem like attributing the property of insolubility to a compound before its formation.”



The question in the former of these sentences, whether it is supposed, on my Father's theory, that when sulphate of soda and muriate of lime are mixed in solution, all the sulphate of lime formed by mutual decomposition will be precipitated, is founded obviously on an assumption. There is no evidence, that, in such an experiment, any more sulphate of lime is formed than what is thrown down. Since after the deposition of part of the saline matter, the quantity of the solvent is sufficient to retain the rest in solution, it cannot be determined in what state these remaining elements exist. It is perfectly possible that the affinity of the water to these elements in the state of their most soluble compounds, may still retain them combined, as muriate of lime and sulphate of soda. Indeed, the latter is rendered the more probable view, by the fact already noticed, that the quantity of insoluble matter, of sulphate of lime for instance, obtained from a mineral water, is, in some cases, greater than what could alone be dissolved in the water. In such instances, we must suppose, that the solubility of the salt is increased by its being accompanied by other salts; and in what more probable way can this be explained, than by supposing the solvent to establish the combination of the elements into the most soluble salts? This objection thus rests upon no evidence when applied even to saline solutions, in which the proportion of liquid is not more than sufficient to retain the different compounds in solution; and it applies still less to mineral waters as they usually exist, the proportion of the solvent being in them generally much greater than what is necessary to prevent re-action of the ingredients, and precipitation. Considered in another point of view, it is indeed an argument rather favourable to Dr Murray's opinion, as the consequence which it predicts actually happens. In the concentration of saline solutions, it certainly might, as Mr Phillips states, be inferred, on Dr Murray's view, that a considerable portion of the saline matter should be precipitated at a certain point, the influence of cohesion and chemical affinity co-operating to produce re-action. Accordingly this, as has been mentioned, is exactly what happens. In the evaporation of such solutions, as of sea water, when the concentration has been carried to a certain extent, a considerable part of the saline impregnation



is deposited: this deposition diminishes in the subsequent evaporation, and at length ceases before the liquor has been wholly dissipated,—a result exactly conformable to Dr Murray's view, but the reverse of what should happen on the common opinion.

The other objection made by Mr Phillips, that “to suppose that sulphate of lime will be formed, if there be not water enough to hold it in solution, seems like attributing the property of insolubility to a compound before its formation,” is one rather applying to Berthollet's doctrine of the influence of cohesion and other extraneous forces on attraction, than to Dr Murray's views. The latter, indeed, derive much probability from the general principles relative to affinity, so ably developed by Berthollet; and it may not perhaps be easy to give a clear explanation of them without reference to these principles; but there are a number of facts unconnected with Berthollet's doctrine, which give support to my Father's opinion, and on which it may be maintained, whatever may be the manner in which these are explained. The difficulty has been generally admitted, and will be found fully stated by my Father, in his System of Chemistry, vol. i. sect. 5, of conceiving in what manner, on Berthollet's doctrine, the extraneous forces of cohesion, elasticity, &c. operate, and how they can be said to determine the formation of a compound, when apparently they are rather properties of compounds already formed. Yet that these forces do exert a powerful influence in modifying affinity, appears to be established by ample evidence. The striking fact, that in almost every instance in which binary combinations are established among three or four bodies by the medium of solution, these combinations are the ones which are least soluble, that is, those on which cohesion acts most strongly, is of itself almost sufficient to prove that the external forces which modify attraction are those which principally determine the results. The attraction of cohesion may be conceived, on Dr Murray's view, to exist in a saline solution, overcome only by the power of the solvent; and hence, when the affinity of the latter is lessened by the diminution of its quantity, the cohesion causes the production of insoluble compounds, as it would produce the crystallization of a salt from a saturated solution evaporated; and *vice versa*, the power opposed to this,



namely, the affinity of the solvent, may be inferred, as has been already explained, to produce, when it is aided by increased quantity, the reverse effect of establishing those combinations which are most soluble. Whether the theory of these changes be regarded as probable or not, and as yet no argument has been brought forward which appears to me to lessen its probability, the evidence that the changes do, to a greater or less extent, happen, seems to be sufficiently strong. I may merely refer to the different facts that have been brought forward,—to the variation of results according to the methods of analysis employed,—the peculiar manner in which the ingredients of a saline solution are deposited during evaporation,—the difference in the products when quantities of other salts are added to the mineral waters before concentration,—the fact, that larger quantities of insoluble matter are obtained from some waters by evaporation than what can be re-dissolved in them,—the experiment which I made to detect the existence of a supposed incompatible alkaline salt in a dilute solution, and the unequivocal result which it afforded,—and, finally, the medicinal powers of mineral waters, inexplicable on any other view, to show that it is not a mere hypothesis which has been proposed and illustrated, but a general inference deduced from a number of facts, independent of any theoretical explanation.

The last of these arguments, that of the accordance of the doctrine with the medical virtues of mineral springs, has been also called in question by Mr Phillips, in the following words: “ It has  
“ indeed been attempted to strengthen Dr Murray’s position, by  
“ arguing from the effects which certain mineral waters produce,  
“ or are supposed to produce, and which, according to common  
“ views, contain only sulphate of lime and muriate of soda : these  
“ waters are imagined to owe their good effects to containing not  
“ sulphate, but muriate of lime. It would, however, I think, re-  
“ quire numerous experiments to prove that the same quantity of  
“ lime is more active as a medicine when combined with muriatic  
“ than with sulphuric acid, when exhibited in equal quantities.  
“ I do not deny, but I question the fact ; and if it should be proved,  
“ it may, as far as I am competent to give an opinion, be derived  
“ from the muriatic acid as from the lime.”



I may be permitted to express some surprise at the statement here made by this able chemist. There is scarcely a maxim in medicine more generally correct, than that the most soluble compounds of a body are the most active remedies which it forms. Thus, in the instance of barytes, an earth which is in many respects analogous to lime, the muriate, which is soluble, is an active substance, indeed in large doses is poisonous, while the insoluble sulphate is perfectly inert. No one has ascribed any activity to sulphate of lime as a medicinal agent, while muriate of lime has been much extolled in various diseases, and has at least been shown to possess some energy by proving poisonous to animals. That sulphate of soda and muriate of lime are, upon the whole, more active salts in a medical point of view than muriate of soda and sulphate of lime, is a position which certainly does not appear to me to require to be formally proved. As to whether the effects arise from the muriatic acid or the lime, this is a question of little importance, and not susceptible of a direct answer: the most probable supposition obviously is, that they must modify each other's action; and the consequence of such modification is frequently an agency very different from that of either of the elements.

To some, the second view given by Dr Murray, that the acids and bases may be in a state of simultaneous union, has appeared one more probable than that they are arranged into the most soluble binary compounds. This no doubt may be maintained; for as Dr Murray remarks, there is no conclusive proof of the actual existence of binary compounds previous to their being obtained by crystallization or precipitation; nor is there any direct improbability in the assumption, that in elements existing in a state of solution, having all of them mutual attractions, and exerting at the same time an attraction to the common solvent, an equilibrium may be produced, producing simultaneous combination, and mutual neutralization. The opinion, however, is one less probable; for if followed out, it will preclude any inference being drawn from specific qualities which may be observed in the compound, and will be inconsistent therefore with the conclusions which, in many cases, we are able actually to form. It is probable, likewise, that from the operation of different forces of attraction, and the influence of the solvent



exerted more powerfully, in consequence of its relation to cohesion, to some substances than to others, binary combinations exist. Even the opinion of simultaneous combination affords a more satisfactory explanation of the powers of mineral waters, than the common opinion does ; for the elements in such a combination may form an active compound. It is only on the assumption, that the products obtained by evaporation are the ingredients, that the difficulty exists ; the very process of evaporation causing the combinations to pass into that state in which the least active compounds are formed.

Mr Phillips has objected to Dr Murray's views, because they are in some measure connected with the doctrines of Berthollet. Berzelius, on the other hand, has objected to them, that they are not sufficiently conformable to Berthollet's opinions. The following remarks have been made by this distinguished chemist, in his elaborate analysis of the Carlsbad waters : " Murray first directed the attention of chemists to the fact, that the analysis of a mineral water often gives the ingredients, in the state of compounds, totally different from those which existed originally in the water. This is very true ; but he overlooked the difference between the results of the analysis and the actual relations of the substances. Berthollet's investigations respecting the action of chemical masses, in conjunction with that of the relative affinities, had already long before given a satisfactory answer to this question. He has demonstrated, that if a number of salts, which do not decompose each other, according to the usually admitted laws of affinity, be dissolved in water, a decomposition nevertheless ensues to a certain extent ; a portion of each acid uniting with a portion of each base ; so that combinations are formed between the whole of the substances individually which exist in solution. Thus, if caustic soda be mixed with sulphate of potash, a certain quantity of sulphate of soda is formed, and the acid is divided between the bases in such a manner, that the uncombined portions of each correspond. If the soda were previously combined with the muriatic acid, the decomposition would be still more extensive ; because a portion of the muriatic acid would at the same time unite with the potash. Two salts were originally dissolved in the water ; but these



constitute four, so long as they remain in solution ; if the water be evaporated, the two are again recovered ; for the reasons which have been so ably developed by Berthollet. Should it be asked, what quantity of each of these four salts exist in solution ? we must allow, that so long as their amount cannot be ascertained by actual analysis, the question must remain unanswered. These quantities depend, in the first place, upon the respective quantities of the two salts originally mixed ; and, in the second, upon the relative attractive forces of the acids and bases. The former of these points may be easily ascertained ; but we as yet possess no data for a precise determination of the latter. Could we express the relative attractive forces of each individual substance in numbers, in the same manner as we express its specific heat, or its specific gravity, it would then become easy to perform this calculation from the results of an ordinary analysis. As yet, however, not one of these relative affinities is so thoroughly understood, that its precise amount can be compared with that of another ; and it is therefore altogether impossible to determine with certainty, from the results of an analysis, to what extent the acids and bases had been combined with one another in the original solution. At present, the utmost we can accomplish is to state the direct results of an accurate analysis. Theory informs us, that the substances constituting our result are different from those which actually existed in the water ; but we should be wrong to associate them with one another in any other manner, because such an arrangement could have for its basis nothing better than conjecture." Such are the observations of Berzelius ; and, in conformity with them, he has stated the saline ingredients of the Carlsbad waters, as they are obtained by evaporation, that is, in the state of the most insoluble compounds, which their ingredients can form.

It certainly cannot be objected, that Dr Murray neglected any part of the doctrines of Berthollet, as there is perhaps no chemist who has illustrated them more fully, or applied them more extensively to the phenomena of chemistry, as will be apparent on an examination of any of his works. And the view of the nature of mineral waters which he has proposed was, in a great measure, deduced, and derives important support, from the opinions of Ber-



thollet relative to the influence of cohesion, and quantity of matter, on affinity, which Berzelius appears to have overlooked. Nor did Dr Murray affirm, that the arrangement of the elements into the most soluble compounds was the only possible supposition. Had Berzelius examined the original memoir of Dr Murray, he would have found it distinctly pointed out, that the only certain statement that can be made relative to the composition of a mineral water, is to enumerate separately its elements, that is, the acids and bases which exist in it, with their quantities, as determined by analysis ; and that as to their mode of union, they may either be supposed to be in a state of simultaneous combination ; or as forming the most soluble compounds, the opinion which he regarded as most probable ; or that they may exist in the state of the least soluble compounds, the most improbable view of the three, and for which the only argument is, that they are so obtained by evaporation. Berzelius, after admitting, that, to a greater or less extent, the second of these views must be correct, and after adducing arguments in its favour, concludes with adopting the last, and remarks, that Berthollet has given a satisfactory view of the question, which yet, when developed, throws doubt and uncertainty, as he states, on the whole subject.

The view given by Dr Murray was thus not so limited as Berzelius states ; nor does the intermediate doctrine, which the latter conceives to flow from Berthollet's investigations, give any clearer or more certain elucidation of the question. It may now be inquired, whether it is justly deduced, and whether it is in itself probable. That in a concentrated solution, two salts which differ little in their degrees of solubility, and are thus little affected by the two important circumstances of cohesion and the quantity of the solvent, will suffer a partial decomposition, and thus produce four salts, is a result perfectly possible, and which can be proved not unfrequently to happen.

But in opposite circumstances, such an interchange of elements is much less probable. All the instances of this nature given by Berthollet were between salts little different in their relation to cohesion, elasticity, and the other forces modifying affinity ; or, where they were not, the quantity of one of the substances required to be increased to a great amount in proportion to the other,



to produce such effects. But with regard to the incompatible salts existing in mineral waters, as muriate of lime, and sulphate and carbonate of soda, the circumstances being very dissimilar, the result is necessarily different. If equivalent quantities of these, in concentrated solutions, are mixed together, it will be found that no portion of either of them will remain unchanged; an insoluble compound will be precipitated, and a soluble salt will remain in the liquid, and there will be no division and participation of any of the elements. And where the solution is so dilute that this precipitation does not happen, another force is introduced in the place of cohesion, namely, the affinity of the solvent, aided by its large quantity, which will, in like manner, prevent any such partial decomposition, and will retain the ingredients in the state of those salts on which it acts with most power. Berzelius, in objecting to Dr Murray's view, seems to have altogether neglected the very principle on which it explains the results, namely, the force of the solvent in opposition to that of cohesion; and to have fallen into the mistake, not an uncommon one among chemists, of regarding a saline solution rather as a mixture of fluid salts than as a chemical combination of salts with a liquid. When we consider how important the affinity of the solvent must be, in the case of a mineral water, in which usually only a few grains of saline matter are dissolved in a gallon of fluid, we perceive an agent fully as capable of establishing precise combinations as cohesion; and it is only from reasoning on its action that we can hope to determine the question, which Berzelius regards as impossible to be decided, namely, in what manner the elements are united in saline solutions. Supposing two acids and two bases mixed in solution, which may form two soluble or two insoluble salts, we know that the attraction of cohesion will, when favoured by evaporation, determine the formation of the two latter, and exclusively so. May it not, in like manner, be inferred, that the opposite power, that of the solvent, when it is favoured by its large quantity, will also determine the production of two salts, namely, the more soluble ones, and of them only. In solutions of intermediate degrees of concentration, the salts may partially re-act on each other; but since the one extreme, that of great concentration, produces two insoluble



salts, it is the most probable supposition, that the other extreme, that of great dilution, will give rise to an analogous result.

The only other observations which I shall make in illustration of my Father's opinions, and in reply to such objections as have been made to them, will refer to the following note, which will be found in Dr Marcet's paper on the specific gravity and temperature of Sea Water, (Philosoph. Trans. 1819.) The originality of Dr Murray's views as to the state in which the salts exist in mineral waters has never been doubted; but this note would seem to imply, that his Formula for the analysis of mineral waters had been before put in practice. In the analysis of sea-water, "I followed," says Dr Marcet, "the plan which I had myself pointed out, and actually used, in various analyses, and particularly in that of the Dead Sea, and of an aluminous chalybeate in the Isle of Wight, as may be seen by a reference to these papers. It is satisfactory to observe, that Dr Murray adopted, several years afterwards, from considerations of the same kind, a mode of proceeding precisely similar, and, indeed, that he proposed, in a subsequent paper, a general formula for the analysis of mineral waters, in which this method is pointed out as likely to lead to the most accurate results. And this coincidence is the more remarkable, as it would appear, from Dr Murray not mentioning my labours, that they had not at that time come to his knowledge." If this statement be meant to question the originality of Dr Murray's formula, nothing can be more unjust, and it is to be regretted that so able an analyst as Dr Marcet should have made so inaccurate a remark. The formula proposed by Dr Murray followed directly from his views of the nature of saline waters, and these views had been entertained by no one before him. I have carefully examined the analysis of the water of the Dead Sea, and have found in it no ground for such an observation, nor any principle or statement which could have led to the construction of Dr Murray's formula, any more than what may be learnt from numerous other analyses conducted by the method of precipitation. The mode of separating the principles of a mineral water by the use of re-agents, was discovered neither by Dr Murray nor Dr Marcet: it has long been employed; but the selection of it as the most accurate method, and one not subordinate to that by evaporation,



with the ingenious mode of converting all the bases into muriates, of successively removing all the acids but the muriatic, and all the bases except the soda, employing only one portion of the water during the whole operation, and of obtaining the muriatic acid and the soda as the last products in the state of muriate of soda, constitute a regular process of analysis equally simple and elegant, which has been proposed in this form by no other person. The reason of my Father's giving the preference to this method arose, as may be learnt from his Memoir, not from comparing the different modes of analysis, nor from any examination of former analyses, but from the peculiar views which had occurred to him, and which obviously led to its adoption as one equally certain, and more accurate than that by evaporation.

The only circumstance in which Dr Marcet's analysis of the water of the Dead Sea resembles the method proposed by Dr Murray is, that from the saline ingredients of that water being almost entirely soluble muriates, as had been previously discovered by Lavoisier, the method of separating the bases by re-agents, in some degree similar to that recommended in the formula, was followed, as no other could well be employed; and Dr Marcet farther states, that it produced the most accurate results. Yet no general rule was deduced from this instance, nor was there any application of it to waters containing other salts. In the individual steps, instead of the methods being "precisely similar," the difference is still greater. Had the analysis been conducted in the manner pointed out in the formula, a given quantity of the water would have been measured; from which the sulphuric acid would have been first removed by muriate of barytes; then the lime separated by oxalate of ammonia; next the magnesia, by Dr Wollaston's method of forming a triple phosphate, which being then unknown, was, of course, not employed, and of itself makes a considerable distinction; and, lastly, the soda would have been obtained in the state of muriate of soda, from which the quantity of muriatic acid might be calculated. Instead of which, Dr Marcet removed the bases from separate portions of the water, a method less convenient, less accurate, and which, in cases where only a limited quantity of the water subjected to analysis can be obtained, will be scarcely practicable. In place also of leaving the



muriatic acid to the last, Dr Marcet removed it in the middle of the analysis by nitrate of silver, a method which, by introducing a new acid, and removing the muriatic acid, would entirely destroy the unity of the formula, which is its principal merit. The muriate of soda likewise was not obtained by Dr Marcet; but its quantity, and that of the soda, were inferred only from calculation, another important deficiency in his method. These remarks may be sufficient to show, that there is no striking coincidence between the method of Dr Murray and the analysis of Dr Marcet, that the latter differs only in an accidental circumstance from common analyses, and that, even in so differing, it is still as dissimilar as they to the general formula which has been stated.

In the Appendix will be found a table of the composition of various mineral waters, taken from the best authorities, and adapted to the principle that has been illustrated, that the elements probably exist in the state of the most soluble compounds. If the older view be considered preferable, the statements may easily be altered to agree with it, by arranging the ingredients into the least soluble combinations. It has been supposed, it may be noticed, that the salts in mineral waters may exist in proportions bearing relations to their atomic weights; and from some calculations which I have made, there seems to me to be much ground for this opinion.

The practicability of imitating mineral waters has engaged the attention of chemists. With regard to the saline waters, there seemed to be no difficulty in imitating them, by simply dissolving the salts, detected by analysis, in the same proportion of water. The solution could also be impregnated with carbonic acid gas; and even with sulphuretted hydrogen, and by the medium of carbonic acid, it might receive an impregnation of iron. Artificial waters have, accordingly, been prepared in this manner, as substitutes for the natural ones. It is obvious, however, that, as this mode of preparing them proceeded on the erroneous supposition, that the products of analysis were the real salts in the waters, such imitations could not be successful. Indeed, in most cases, it is found to be impossible to dissolve the quantities of



carbonate and sulphate of lime, which a saline water yields during evaporation, in a similar quantity of water. Hence these artificial waters have never been found of any utility. If prepared, however, on Dr Murray's principle, by mixing proper quantities of soluble salts together, they will be found more active, and may be of considerable efficacy. The saline waters can, in this way, be imitated with facility, by observing the proportions which will be found stated in the table. It is rather more difficult to impregnate them with carbonic acid, in imitation of the carbonated waters. Dr Murray has given the following method of preparing an artificial Seltzer water :—" Pour a pint of water into a strong bottle ; introduce, by means of a long funnel reaching to the bottom of the bottle, 35 grains of muriatic acid, of the strength usually met with in the shops, then drop in three grains of pure white marble in coarse powder, and close the bottle ; when these are dissolved, add 5 grains of the common carbonate (subcarbonate) of magnesia, and after their solution, add 27 grains of bicarbonate of soda ; close the bottle accurately, shake and invert it : in a short time a perfect solution takes place, and a transparent liquor is obtained, which sparkles when poured out, and has a pleasant taste." In this process, by using free muriatic acid, and dissolving in it the different bases combined with carbonic acid, the soluble muriates are formed in the due proportions, while the carbonic acid disengaged is retained in solution by the water and by the slight degree of pressure from closing the bottle, and thus an artificial carbonated water is formed, of exactly the same composition as the natural Seltzer water. In the same ingenious manner the other carbonated mineral waters may be imitated ; but none of them are equal in reputation to that of Seltzer, as they are neither so agreeable nor efficacious. Chalybeate waters may be imitated by adding a small quantity of solution or tincture of muriate of iron to the appropriate saline solutions.



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## BOOK VIII.

### OF VEGETABLE COMPOUNDS.

THE compounds which are the products of the chemical processes carried on in the vegetable, and also in the animal system, have peculiar chemical characters by which they are distinguished from the compounds which exist in the mineral kingdom, or which are capable of being artificially formed. Their composition is more uniform with regard to the principles of which they are composed, but more complicated with regard to the number of elements existing in simultaneous combination, and more diversified in the proportions and mode in which these are united. Carbon, hydrogen, and oxygen, are their chief constituent principles, to which are sometimes added, in smaller proportions, nitrogen, sulphur, phosphorus, potash, lime, and iron; and it is from differences in the proportions, and in the modes of combination, that the immense diversities of properties by which they are distinguished are derived. These principles, too, are not united in binary compounds, but in more complicated states of union; their affinities are therefore more nearly balanced, and of course are more easily subverted. Hence the susceptibility of decomposition, by which vegetable and animal substances are distinguished; they are liable to spontaneous change from the mere re-action of their elements; they



are, even at common temperatures, acted on by the oxygen of the atmosphere; and at elevated temperatures, their existing composition is entirely subverted. In all the decompositions, too, to which they are liable, their principles are not disengaged insulated, but in new states of combination; and as their composition with regard to the ultimate principles is much alike, the products of this analysis in the different individual substances are extremely similar. And, lastly, as we are incapable of balancing the attractions of the principles of which they are formed, or of placing them under the circumstances under which they were brought into union in the vessels of the animal or plant, we can seldom by artificial arrangements form compounds of a similar nature.

The vegetable compounds are more simple in composition than those formed in the animal system. They consist chiefly of carbon, hydrogen, and oxygen, and more rarely contain nitrogen, sulphur, or phosphorus; hence their composition is more permanent, as it depends on a less nice adjustment of affinities; and the products of their analysis are less complicated. It has, in general, been found difficult to apply the doctrine of definite proportions to the determination of the exact constitution of vegetable products: in a number of cases, however, this has been recently accomplished, and the elements have been shown to exist in union in certain and fixed proportions, or, as it is commonly expressed, a certain number of atoms of each are combined together: Thus, sugar is stated to consist of one atom of carbon, one of oxygen, and one of hydrogen; acetic acid, of carbon 4 atoms, oxygen 3 atoms, hydrogen 2 atoms. The composition is frequently even more complicated: Thus camphor is calculated to consist of carbon 10 atoms, oxygen 1 atom, and hydrogen 9 atoms; benzoic acid, of carbon 15 atoms, oxygen 3



atoms, and hydrogen 6 atoms. Two opinions may be entertained with regard to the arrangement of these elements: they may either be supposed to be in simultaneous combination, or in the state of binary compounds united with each other. The former is perhaps the more probable opinion; but there are a number of substances, the constitution of which is usually stated on the latter view: thus, oxalic acid is commonly said to be a compound of one atom of carbonic oxide with one atom of carbonic acid.

Vegetable compounds are formed by actions subservient to the process of vegetation, and are derived from combinations established by that process among the elements of the substances absorbed by plants. Hence the relation of vegetation to chemistry, and the advantage of considering it so far as it is a series of chemical operations, before proceeding to the history of the compounds themselves.

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CHAP. I.—OF VEGETATION, AND THE FORMATION OF  
VEGETABLE COMPOUNDS.

VEGETABLES are, like animals, endowed with life. It has been attempted, indeed, to account for the functions they perform from their peculiar mechanism, and the action of mechanical power: the rise of the sap, and the propulsion of their fluids, have thus been ascribed to capillary attraction, and the motion of different organs to the elasticity of fibres. But such causes are utterly inadequate. The absorption of external matter, the movement of the fluids direct and retrograde, the secretions whence new products are formed, the motions of the leaves as they are excited by light and other external agents, the developement and



growth of new parts, and the formation and evolution of the embryo plant,—are phenomena inexplicable on any principles of mechanism, and so strictly analogous to corresponding phenomena in the animal system, that they must be referred to a similar cause.

Vitality in vegetables observes even the same laws as that by which it is regulated in the animal frame. The motions and functions dependent on it require to be excited by the application of external agents: if these are withdrawn, the functions languish or cease; if they act too forcibly, the vital power is impaired; if they have been previously abstracted, more vigorous action is exerted when their application is renewed; or if too suddenly and forcibly applied, the excitement may produce exhaustion of power. The effects of soil, of moisture, of heat, light, and electricity, on plants,—their sleep, germination, efflorescence, fructification, and decay, afford many illustrations of the operation of this principle in conformity to these laws.

As vegetables and animals are thus endowed with similar powers, there is a similarity in their general structure and organization, and in the functions they perform. In vegetables these are indeed more simple than in the more perfect animals, but still the analogy is easily traced.

The organized structure of vegetables is best discovered in the larger and more perfect plants. These consist of a stem or trunk, which at its insertion into the earth generally divides, forming the root, and at its upper extremity terminates in branches, to which the leaves and parts of fructification are attached. On making a transverse section of any of these solid parts, a difference of structure is observed. In the centre is a soft cellular substance, named the Pith, most abundant in young plants, and not of much importance, as it may be extracted without



injury to the plant. External to this is the wood, more dense and hard : it is fibrous, and is composed of layers or zones formed annually, and varying in density and size as vegetation is more or less vigorous. Over the whole is an outer rough covering, the Bark. This is composed of three parts,—the epidermis, or external rough covering, consisting of numerous layers ; the cellular tissue beneath, composed of fibres interlaced, so as to leave interstices, which appear to be filled with a soft matter of a green colour ; and the cortical layers next to the wood, and approaching to it in structure : through these parts numerous minute vessels run. Next to the bark the layer of wood is soft, and has been named Alburnum.

Attached to the stem or branches are the Leaves. Their structure is fibrous and interlaced, covered on each surface with a fine membrane, and having numerous vessels communicating freely with each other. Their surfaces perform different functions. That of the lower is principally absorption ; water or watery vapour is taken in, when in contact with it ; they also perform transpiration. The upper surfaces appear to be analogous in their functions to the lungs of animals, exposing the sap circulating through the plants to the chemical agency of the light and air.

There moves through the vessels of plants a common juice or sap, supposed to be analogous, in the office it is destined to perform, to the blood of animals, and from changes in the composition of which the products of the plant are formed. The sap, or *common vessels* as they are named, which correspond to the lacteals and pulmonary arteries of animals, rise longitudinally from the root to the upper extremities, passing beneath the cellular tissue of the stem and branches, or through the wood, and conveying the fluid, which is absorbed by the roots from the soil,



to the leaves, where it passes through numerous minute ramifications of these vessels.

There are vessels distinct from these, named the Proper Vessels, in which the common sap has been supposed to suffer peculiar elaboration. They are situated principally in the cellular tissued and internal bark; they appear to descend towards the root, and to convey a fluid in that direction, as, when cut, the liquor which exudes comes from the upper margin of the incision. They in fact convey the sap from the leaves downward, and like the blood-vessels distribute that important fluid to every part of the vegetable.

As the common vessels can be traced from the root to the leaves, and the proper vessels descend in the opposite direction, it appears to follow, that any connection between them is established in the leaf. Darwin accordingly shewed that the large vessel, or bundle of vessels, which runs from the leaf-stalk through the centre of the leaf to its apex, is formed by the union of smaller sap-vessels; that its purpose is to distribute the sap over the surface of the leaves in minute ramifications, in which it may be exposed to the action of the air and light; and that the sap thus changed is brought back by other vessels which pass along the under surface of the leaf, unite at the commencement of the stalk, and form the proper vessels; in its progress through which, in different parts of the plant, the juice undergoes farther changes. He stated some experiments on the absorption of coloured fluids, which accorded with this view; and it has also been established by the experiments of Knight.

Another set of vessels have been observed in vegetables, of a spiral form. They are found around the pith, in the slender branches, the leaf-stalk, and the petals of the flower. As they are always empty, they have been sup-



posed to convey air; others have supposed them to be absorbents, which contract when cut, and discharge their contents. Knight regards them as subservient to the sap-vessels, and supposes, that by some mechanism they facilitate the propulsion of the sap.

The functions performed by vegetables subservient to the formation of their chemical products, are Absorption, Perspiration, Respiration, and Secretion.

Absorption is performed by vessels arising from the roots, and probably also from the bark and leaves. From the soil a large quantity of water appears to be taken up, holding dissolved the soluble parts of the vegetable and animal matter which the soil contains, and a portion of its saline and earthy matter. This absorbed fluid appears to be the source of the sap: in its ascent it is changed in its qualities, acquiring greater specific gravity, and holding a larger portion of matter dissolved; changes which may arise in part from the action of the vessels through which it is propelled, and partly from the intermixture of the proper juices of the plant. The additional portion of matter in the sap is also supposed by Darwin and Knight to be derived from the extraction of solid matter from the wood. It is conceived that when vegetation is vigorous, as in summer and autumn, nutritious matter is formed in excess, and is deposited as a reservoir of nutriment in the Alburnum, or in herbaceous plants in the roots; that on the revival of vegetation, this is dissolved by the ascending fluid, which is then most abundant, and serves for the formation of new buds and leaves. According to the extent of the changes which it suffers, and probably also according to the materials from the soil, the sap varies in its qualities. Vauquelin found, that it always holds dissolved a considerable quantity of saline



matter, principally acetate of potash and lime, and sometimes carbonate of lime, with small portions of sulphate, muriate, and nitrate of potash; it contains, too, vegetable matter, principally extract and tannin, and sometimes sugar; probably derived from intermixture of the proper juices; and it is usually largely impregnated with air.

Perspiration is observed in plants, and when vegetation is vigorous, or under exposure to heat or light, takes place to a considerable extent. The perspired fluid appears to be water, with a slight impregnation of vegetable matter.

Respiration, or the function by which changes are produced in the composition of the surrounding air, is performed by vegetables by the medium of their leaves, is necessary to sustain their life, and is probably connected with the chemical changes which constitute vegetation. Considerable difficulty has been experienced in determining the nature of the reciprocal action exerted between a growing plant and the surrounding atmosphere.

Priestley observed that plants absorb carbonic acid from atmospheric air, and communicate to it oxygen; and this suggested the speculation, that vegetables and animals stand opposed to each other in the changes they produce in the atmosphere, and by this opposition preserve it at its due purity and composition. This view, interesting from its apparent adaptation to the economy of nature, was received without being submitted to very strict evidence. Even the experiments of Priestley afforded discordant results, and proved, that in some cases the changes produced in the air by vegetables are the reverse of those whence his conclusions were drawn; and in those made by Scheele, the deterioration of the air, and the production of carbonic acid gas, were uniformly observed.

A fact ascertained by Ingenhouz appeared to point out the principle from which this discordance might be ex-



plained. He observed, that the evolution of oxygen gas from the leaves of vegetables takes place principally when they are under exposure to solar light; whence he inferred, as the result of an extensive series of experiments, that "oxygen is elaborated in the vessels or other organs of vegetables, by a vital action, excited and sustained by the light of the sun;" and he added a number of facts in proof of the conclusion, that the organic structure of the vegetable is necessary to this production of oxygen, that it is the result of a function performed by the plant, and directly connected with its economy. The production of oxygen he found at the same time to be considerably dependent on the nature of the water under which the vegetable was immersed; and it has been since shewn, by the experiments of Sennebier, Woodhouse, and Saussure, that it is much connected with the presence of carbonic acid, so that in water entirely free from this acid, the evolution of oxygen is inconsiderable, while in water impregnated with carbonic acid the production of oxygen is abundant. It may be inferred, therefore, that it is principally from the decomposition of carbonic acid in the water that the oxygen is evolved. Some have supposed even that this decomposition is produced by the action of light alone, and that the vegetable matter affords merely a surface on which it acts on the water or the carbonic acid in a favourable manner,—a supposition, however, which appears to be refuted by various facts stated by Ingenhouz, which prove the necessity of organic structure, and organic action, to the evolution of oxygen; particularly that other substances, which equally afford a surface, as silk, have not the same effect; that the quantity evolved is greater, as the leaves are in a state of vigour; and that the evolution ceases when their life or organization is destroyed.



Still it is more satisfactory to determine the changes which the entire vegetable produces in the surrounding air, in its natural situation ; and on this subject many experiments have been made. Priestley in general found, that air vitiated by respiration or combustion has its purity restored by a growing plant, and that, by introducing the flexible shoots of plants into jars containing air, the air is ameliorated. Ingenhouz observed that plants confined in air, containing a portion of carbonic acid gas, decompose it, and produce oxygen when under exposure to solar light ; but if the solar light is excluded, the reverse changes take place, oxygen is consumed, and carbonic acid formed. With this the experiments of Sennebier nearly correspond. Woodhouse, at a later period, drew similar conclusions, that plants by a vital action are able to convert carbonic acid into oxygen. In his experiments, indeed, carbonic acid, he admits, was frequently formed, and oxygen consumed ; but not, as he supposed, from any function of the vegetable, but rather from the chemical action of the oxygen on the carbonaceous matter of the plant ; and the change more directly produced by the vital action of the vegetable, excited by solar light, he conceived is the decomposition of carbonic acid absorbed from the air, and consequent evolution of oxygen. As this change, however, even in favourable circumstances, goes on slowly, and as the quantity of this acid diffused in the atmosphere is inconsiderable, vegetation, he supposes, can have little effect in preserving its purity.

The investigation of this subject has been prosecuted still more minutely by T. Saussure. The view suggested by his experiments is, that carbonic acid is decomposed by growing vegetables, as the result of the process of vegetation ; the carbon is fixed in the vegetable matter, contributing to the growth of the plant, and the formation of its



products; part of the oxygen is also retained, and the remainder is evolved. Hence, when growing plants are placed in atmospheric air, to which carbonic acid has been added, and exposed to solar light, the carbonic acid, if not in too large quantity, disappears, oxygen is evolved, vegetation is vigorous, and the proportion of carbon in the plant is increased. It is this, according to Saussure, which is the source of the carbon in vegetables, for when they are made to vegetate in pure water, and in atmospheric air, deprived of carbonic acid, there is, he maintains, a mere enlargement of bulk without any addition of weight. At the same time, the action of light is necessary to these changes. If it is excluded, the presence of carbonic acid gas is injurious, and no sensible quantity of it is decomposed; and a growing plant placed in common atmospheric air, under the exclusion of light, consumes oxygen, and forms carbonic acid. If the light be admitted, the reverse changes are established, and thus, under the alternate admission and exclusion of light, little sensible change is produced in the constitution of the air.

Lastly, the able researches of Mr Ellis have given another view of the changes produced by vegetables in atmospheric air, and of the connection of these with vegetation, nearly the reverse of that advanced by Saussure, though admitting a number of the same facts. His experiments prove, that growing plants, in all periods of vegetation, consume the oxygen of the air, and form carbonic acid in quantity equivalent to the portion of oxygen consumed; this takes place not only in darkness, but even under clear day-light; and it is only suspended, and the reverse changes established, by the direct action of the solar rays. Carbonic acid is not necessary, he conceives, to their growth, for they die when it is abundantly supplied, if oxygen is not present; while they live and flourish as



long as oxygen is supplied, though carbonic acid be completely abstracted.

It appears to be established by the general results of the experiments that have been made on this interesting subject, that growing vegetables produce very different changes in the air which surrounds them, according as they are exposed or not to the solar rays. Under this exposure they decompose carbonic acid when it is present, either in its elastic form or condensed by water, and exhale oxygen; when excluded from this, even though diffused light be present, they produce the reverse changes, consume oxygen, and form carbonic acid.

The question therefore obviously is, which of these series of changes is the result of the natural function of the plant connected with its growth and the formation of the products. And on this point Mr Ellis has forcibly remarked, that as so many plants grow and form their products without being exposed to the rays of the sun, and as at certain seasons, and in many climates, the degree of this exposure is inconsiderable compared with their seclusion from it, we are led to the conclusion, that it cannot be essential to their growth, but that the changes which they more constantly produce, must be those on which vegetation depends.

This opinion may be just; yet the subject is not altogether free from obscurity; for, independent of the circumstance, that there is still some discordance with regard to some of the facts connected with it, it must be admitted as singular, that plants can without injury so change the state of the functions they perform, as at different times to produce changes precisely the reverse of each other, though extremely important in themselves; and farther, that they should exist in greatest vigour, and form their peculiar products in greatest perfection, generally in those climates,



and universally in that season, in which they have, from situation with regard to solar light, been exerting to the greatest extent that very function with regard to the air, supposed to be least natural to them, or the reverse of that to which their economy is adapted, and which they usually perform. We have the farther difficulty, if we adopt this view, of accounting for the origin, (particularly in the case of plants growing when supplied only with water and atmospheric air,) not only of the carbon which makes part of their substance, but of the much larger quantity which must be spent in this formation and evolution of carbonic acid. And, lastly, the experiments of Saussure, if they are correct, prove, that the decomposition of carbonic acid by plants, instead of being an unnecessary process dependent on the accidental chemical agency of solar light, is essential to their growth; for he found, that if the small portion of carbonic acid which atmospheric air naturally contains were removed, by washing with lime-water, the vegetable to which such air was applied merely expanded, without any real addition of vegetable matter, while, when supplied with water, and with atmospheric air in its natural state, the proportion of vegetable matter increased with its growth, proving that it had fixed the carbon of this carbonic acid.

It may be remarked, in concluding this subject, that the changes effected by plants in a state of vigour on the surrounding air, appear to be less than have been usually imagined; water is more essential to them, and they are unquestionably much less dependent than animals on the surrounding air. They require also a smaller supply of nutritious matter, as their growth is more slow, and they lose less by any excretion. There appears, too, to be a much greater diversity in plants than in animals with regard to their relation to the air, some affecting it more slowly, others pro-



ducing changes in it more speedily, and some being injured by one gas, in which others live sufficiently well.

Vegetables are capable of acting on the other aërial fluids besides atmospheric air or carbonic acid; but the facts on this subject are somewhat discordant, and are less interesting, as having little connection with vegetation. Pure oxygen gas, according to some, increases the vigour of vegetation, according to others is injurious to it; the latter effect probably arises from its attracting carbon from the plant and forming carbonic acid. Nitrogen is not capable of sustaining vegetable life for any long period. Carbonic acid is peculiarly injurious, if its noxious quality is not counteracted by exposure to solar light. Hydrogen does not appear to be so hurtful to vegetation, and, according to Humboldt, is even capable of supplying, to a certain extent, the place of light, enabling plants to retain their green colour when placed in darkness.

Changes analogous to those produced by the leaves on the surrounding air, are produced by the action of other parts, particularly the stems and green shoots. The leaves, however, are the proper respiratory organs of plants, and their importance is shewn by the fact, that when they are destroyed during the period of rapid vegetation, the plant decays and dies. The under surface of the leaf appears, it has been mentioned, to perform the functions of transpiration and absorption of watery vapour, while at the upper surface the chemical changes produced by the action of light principally take place. The green parts of plants were considered as those more peculiarly adapted to the emission of oxygen. Mr Ellis has remarked, however, that they rather become green in consequence of that emission: the white colour produced by seclusion from light, appears to be owing to the retention of carbonic acid; when the plants are exposed



to light, this acid is decomposed and oxygen exhaled, and the green colour appears, probably in part from the action of alkaline matter.

Secretion, or a process analogous to it, is performed by vegetables; in other words, from the common juice or sap very different products are formed, by the action of the vessels giving rise to new combinations of the principles it affords. These changes have been supposed, but without any direct proof, to be produced principally in the utricles or bundles of vessels situated in the stem and other parts. The secreted products form the chief proximate principles of vegetables, and they are adapted to different purposes in the economy of the plants.

After these observations on the functions of vegetables, we have to trace, as far as can be done, the operation of those substances which are received into the vegetable system, and those processes by which these are converted into the varieties of vegetable matter.

The seed of a vegetable consists of two principal parts,—the Germ, or part endowed with life, and the Cotyledons or Seed-Lobes connected with it, and which, in the commencement of its growth, afford it nutrition and support. In the germ two parts are discoverable,—the radicle, which descends from the seed forming the root, and the plumula which becomes the stem. The germ is connected with the cotyledons or seed-lobes by slender vessels, which ramify through their substance, and unite at their connection with the germ; the use of the cotyledons, it will appear, is to afford nourishment to the young plant, until it is able to absorb materials for its growth from the surrounding soil; hence they are composed of the most nutritious principles, fecula, sugar, gum, and sometimes gluten. When the seed is planted in the ground, or placed in other situations favourable to



its vegetation, it absorbs moisture, and swells; the radicle shoots out, and the substance of the seed-lobes soon suffers a change in its qualities, the fecula of which it principally consists being converted into sugar. This constitutes the vegetable function of germination, the first stage in the process of vegetation.

The presence of oxygen is indispensable to germination. If seeds moistened are placed *in vacuo*, or if they are confined in nitrogen or hydrogen gas, or carbonic acid, they do not germinate; when immersed in water from which atmospheric air is excluded, they swell, and the radicle is formed, but vegetation makes no farther progress; the life of the germ is soon lost, and the chemical decomposition of the matter of the seed takes place. But if atmospheric air or oxygen be admitted, germination commences, and if the seed be placed in a favourable situation, proceeds to vegetation. Humidity is essential to the process, probably by favouring the developement and action of the minute vessels of the embryo plant, as well as the chemical changes, which convert the substance of the seed into matter adapted to its nutrition. A certain temperature, superior to the freezing-point of water, is also necessary, and probably operates by favouring these changes, and exciting the vital powers of the germ. Light rather retards the process, and, under full exposure to it, seeds do not germinate, or if they do, the plant on its evolution is extremely weak. When placed in the soil, therefore, seeds are under the most favourable situation for germination. The direct action of light is excluded, from the looseness of the soil the air is admitted, the due degree of humidity is supplied, and the temperature is preserved uniform.

During germination, the oxygen of the air is consumed, and carbonic acid is formed; the volume of the air is not



sensibly altered ; and as in the change of oxygen by combination with carbon into carbonic acid, there is no change of volume, this proves, that no part of the oxygen consumed in germination is absorbed by the seed, but that it merely combines with a portion of its carbon. From this it must follow, that a seed will lose weight by germination, a fact which has accordingly been established by numerous experiments. Indeed, it is found that the loss of weight is considerable, and much greater than can be accounted for by the quantity of carbonic acid produced ; hence there seems reason to believe, that a portion of the oxygen and hydrogen of the seed escapes in the state of water. By weighing seeds before and after germination, dried to the same degree, Proust found that the loss was equal to a third of their weight. Dr Thomson, however, from a number of careful experiments, estimates it at only one-fifth.

By the chemical changes which occur in germination, the fecula of the seed is converted into sugar. This appears designed to serve as nourishment to the young plant ; being soluble in water, it is absorbed in a state of solution by the vessels of the radicle, which begin to expand ; and a supply of nutritious matter is thus afforded independent of any external source, until the powers of the plant are developed. The necessity of this is shewn by the fact, that if the seed-lobes are removed from the germ, the latter, when placed in the earth, either does not vegetate, or does so very imperfectly, and soon dies.

When germination has been established, the powers of the plant are excited, and its parts expand. The radicle first shoots out, penetrates the soil, and increases in length ; the plumula arises from the ground to form the stem, and the different organs are successively unfolded, according to the structure of the plant. Nutritious mat-



ter is now supplied to it from without ; and from changes in the substances it receives, all its products are formed.

Air and water are the principal vehicles of the food of plants. The soil, except with regard to some vegetables, affords little directly nutritious matter, and scarcely any of the earthy matter is absorbed. The earth in which a plant is made to grow, it has been shewn by experiment, suffers little diminution of weight, though the plant placed in it has increased greatly in bulk. Many vegetables grow when supplied with pure water alone. Parasitic plants, and those which grow on stones or rocks, can derive no nourishment from the earth ; and the analysis of vegetable matter has shewn, that their solid substance, and all their products, are formed of principles very different from those of which the soil is composed.

Water enters largely into the composition of vegetable matter ; but it has also been concluded that it suffers decomposition in the process of vegetation, and that its hydrogen, with a part of its oxygen, contribute to the formation of the vegetable products. The conclusion has been drawn partly from the consideration, that in plants supported on air and water alone, there is no other source whence the hydrogen so abundant in their composition can be derived, and partly from the fact, that vegetables growing in water exhale oxygen, when exposed to the action of solar light, which, it is inferred, must be in part derived from the water which the light enables the plant to decompose.

From atmospheric air, plants, it has been supposed, may receive carbonic acid, and this decomposed may be the source of the carbon, which, with hydrogen and oxygen, is the basis of their composition. In support of this, experiments have been stated by T. Saussure and others, proving that in an atmosphere composed partly of carbo-



nic acid, growing plants cause a quantity of it to disappear, and that when supplied even with the small portion of carbonic acid contained in common atmospheric air, they grow, and increase their quantity of carbon, which they do not do if the carbonic acid of the air has been previously abstracted. The uncertainty of our knowledge of the real changes which plants produce in the atmosphere, throws, however, some doubt on this subject. If their principal action is to absorb carbonic acid and evolve oxygen, the carbon which must thus be separated will probably remain in their composition. If, on the contrary, the change which they chiefly effect is to consume oxygen and exhale carbonic acid, this view cannot be adopted; and we have even the additional difficulty of accounting for the source of the carbon contained in the carbonic acid they discharge. As, upon the whole, it appears most probable, that the total effect of vegetation on the constitution of the atmosphere is conformable rather to the former than to the latter opinion, the common explanation may be received as in a great measure just, that a part (and when the vegetable is supplied only with air and pure water, perhaps the whole) of the carbon comes from absorbed carbonic acid. It would appear, that whatever may be the action performed by the leaves, the roots absorb oxygen, which appears to be conveyed through the plants and delivered by the leaves to the external air; hence it is necessary that the air shall have, in some degree, access to the roots of plants. Whether the advantage derived from the oxygen thus applied is from the stimulus it communicates to the vessels of the plants, or from its chemical agency, is uncertain.

The fact which has been stated, that plants will grow and flourish when supplied with air and water alone, has, it may be remarked, been questioned by some. There



is, it has been contended, a mere developement of parts, without any actual increase of vegetable matter, unless where other sources have existed whence nutrition could be conveyed. Thus, Hassenfratz has affirmed, that in plants which expand when merely supplied with water, as hyacinths, kidney-beans, or cresses, the vegetation is in this situation always imperfect, and the plants, when dried, afford no more carbon than what is contained in the seed or bulb. Saussure remarks, that these and similar plants, if supplied merely with distilled water, though they advance so far in growth, do not come to maturity. And Knight has remarked, that bulbous and tuberose roots contain within them the matter which serves for the developement of their parts, and their growth, to a certain extent. In the celebrated experiment of Van Helmont, in which a small willow was placed in a vessel containing dried earth, and supplied with water for several years, until it had grown to such a size as to have increased in weight from 5 to 169 pounds, though the earth had lost only two ounces of weight; and in other experiments of a similar kind, it has been contended, that sources of fallacy exist, particularly in the foreign matter conveyed by the water with which the plant was supplied.

It may be true, that in many plants, vegetation, in the first stages of their growth, may be little more than an expansion of their substance by the operation of humidity, and the vital powers of the plant; and it is also not to be doubted, that there are many, the growth of which is imperfect unless they receive nutritious matter from the soil. But still these facts are insufficient to invalidate the conclusion, that vegetation may be supported by air and water alone, and that many plants supplied with these will flourish, and form their peculiar products.



This conclusion is in fact established, if we attend merely to the circumstances connected with the growth of a large vegetable, as of any of our common trees. Its roots stretch to no great extent or depth in the soil, and that soil does not require to be renewed, or to receive any supply of manure. Nay, frequently the situation is such, that nothing is afforded but a support by which the plant is exposed to the air, and occasionally supplied with water. Yet the growth of the tree advances, its solid matter increases, and in many of them much vegetable matter is annually lost in the fruit and foliage. It is obvious, that the portion of soil with which the plant can be supposed to communicate could not have contained the matter from which this is derived, and there is no external supply but from water and atmospheric air.

There are, however, many vegetables which require other nutritious substances for their support and growth. This is proved by the most familiar facts in agriculture. Many vegetables flourish only in certain soils; those which require a rich soil vegetate only feebly when made to grow in a poorer, and many exhaust that in which they grow, so that it requires to be renewed by manure.

The two series of facts on this subject apparently opposed to each other,—one proving that vegetables grow when supplied with air and water alone, the other equally proving that vegetation under such circumstances is imperfect, and that a supply of matter more directly nutritious is required,—perhaps admit of being reconciled. In plants which expand rapidly, and soon proceed to maturity, the aid of nutritious matter may be required to bring them to perfection; the developement of their parts may so far exceed the slow supply of principles which they can assimilate from water and atmospheric air, that they decay before their vegetation under such circumstances can



be completed. But in plants which grow more slowly, air and water may afford a sufficient supply. It is accordingly those vegetables which grow with most rapidity, and which afford the largest produce of seed or fruit compared with the plant at the commencement of its growth, that require a rich soil. Such are those plants which are cultivated for the nourishment of animals.

Of the substances which contribute to the growth of vegetables, besides air and water, the most important is vegetable or animal matter in a state of decomposition. This constitutes the richness or fertility of a soil; and its operation probably arises partly from its affording matter already assimilated to the nature of the vegetable, which is directly absorbed, dissolved or suspended in water, and partly from the elastic products evolved during its slow decomposition, which contain the principles required for vegetable nutrition in comparatively a condensed state, and which may also enter the vegetable by absorption, either in the elastic form, or imbibed by the water of the soil.

Besides this species of manure, which is perhaps alone directly nutritious, there are others scarcely less useful, which appear to operate either by accelerating the decomposition of vegetable and animal matter, or by exciting the plant to more vigorous action. Such is lime, the utility of which is sufficiently established, both in increasing the products of vegetation, and improving their quality. The theory of its operation cannot be said to be fully understood; it may in part act by its intermixture with the other earths composing the soil, giving those qualities most favourable to vegetation, which depend on its cohesion; it may also stimulate the absorbent vessels of the root; it may, either in its entire state, or in that of its elements, enter into the composition of the vegetable pro-



ducts ; but its principal operation probably is that of accelerating, by its chemical action, the decomposition of matter which would otherwise remain inert : hence its utility is greatest in soils abounding with vegetable and animal matter ; and when this is exhausted, less advantage is derived from it, until this species of manure is supplied. It acts most powerfully in its pure state, though similar advantages are derived from it, to a certain extent, when it is combined with carbonic or sulphuric acid.

The nature of the soil, with regard to its earthy and metallic ingredients, has likewise an important influence on vegetation. These may have a diversity of effect in exciting the actions of the vessels of the roots : if absorbed even in sparing quantity, they may have a similar effect on other organs of the plant ; and it is obvious, that they must differ in the mechanical support they afford, in the facility with which they allow the roots to extend, and in the force with which they absorb water, and retain it. As these qualities must be various in their relation to different plants, some requiring a more firm support, or a more ample supply of humidity than others, different soils are necessarily adapted for different vegetables. A number of facts relative to the constitution and agency of soils have been established, by the observations of Davy and others, some of which may here be noticed.

The constituents of soil are silica, alumina, lime and magnesia, the two latter in the state of carbonates, or combined with the former, oxide of iron, vegetable and animal matters, and some saline ingredients, particularly muriate of soda, sulphates of magnesia and lime, and phosphate of lime. To form a just idea of soils, it is necessary to conceive different rocks decomposed or ground into parts, and powder, of different degrees of fineness, some of the soluble parts dissolved by water, and that water adhering to the mass, and the whole mixed with



larger or smaller quantities of the remains of vegetable and animal substances in different states of decay. The coarse grains which form the greater part of soil, consist chiefly of the four earths combined or mixed. The other, which is the more valuable part of soil, is similar in constitution, but in a state of impalpable division; the richer ingredients, namely the vegetable and animal matter, are usually also broken down and intimately mixed with the rest. The principal use of the earths is to give support to the plant, and to absorb and retain water for its nourishment. It is supposed, also, that they exert a chemical action, particularly the argil, on vegetable matter, so as to render it more easily taken up by the plant. The carbonate of lime is a very useful ingredient of soil: it communicates the power of absorbing water, without giving too much tenacity. When derived from burnt lime, which has been applied as a manure, and has attracted carbonic acid, it is necessarily in a state of very minute division, and hence forms one of the most valuable additions to soil. Sir H. Davy found a soil from Ormiston in East Lothian, celebrated for its fertility in raising wheat, to contain more than half its weight of finely divided matter, half of which was carbonate of lime, and the rest impalpable vegetable matter. A very fertile soil from the low lands of Somersetshire contained no less than 83 *per cent.* of carbonate of lime in a state of fine division, with only 5 *per cent.* of animal and vegetable matter, and 12 parts of coarse sand; an instance proving that the nutriment of the plants could not be in any great measure derived from the vegetable matter in the soil, but from air, and the water absorbed by the calcareous matter. The carbonate of magnesia present in some soils is derived from magnesian limestone, and is a useful ingredient. In some districts in which this limestone has



been burnt and used as a manure, it has been found very hurtful to vegetation; the reason of which appears to be, that the calcined magnesia, absorbing carbonic acid from the air very slowly, remains for a long time caustic, when it is of course injurious to plants.

It is obvious that different plants will thrive best in very different soils; thus, those which have bulbous roots require a looser and lighter soil than such as have tap roots, or extensive lateral roots. Sir H. Davy found a good turnip soil to contain no less than 8 parts out of 9 of siliceous sand, and was hence very loose in its texture. A soil, celebrated for raising some of the largest oaks in England, that of Lord Fitz-William's park near Sheffield, was more tenacious, containing 1 part out of 6 of clay and finely divided matter; and an excellent wheat soil from Middlesex was still more coherent, containing only 3 parts out of 5 of siliceous sand, a large proportion of argil, and 11 *per cent.* of animal and vegetable matter. The tenacity of soil is derived generally from argil, and a large quantity of impalpable matter.

It has been found, that an intermixture of ingredients is essential to the fertility of soil. No soil containing 19 parts out of 20 of any single ingredient, even though that be in general a valuable constituent, will support vegetable life. Thus, the soil of Bagshot heath contains only 1-20th of impalpable matter, and is accordingly barren; on the other hand, the surface of a peat moss, which consists wholly of rich vegetable matter, is equally barren. The power of absorbing moisture from the atmosphere is greatly conducive to fertility, in a climate that is not very moist. Sir H. Davy found 1000 grains of the soil from Ormiston, dried at  $212^{\circ}$ , to gain in an hour, by exposure to a damp atmosphere, 18 grains; the soil of Bagshot heath, under the same circumstances, gained only 3 grains. Various



other observations have been made relative to soils : these, however, are necessarily of limited application, as the qualities of the soil are to be compared, not only with regard to the particular vegetables it supports, but according to the nature of the subsoil, the declivity, and the humidity and the temperature of the climate.

Lastly, in the process of vegetation, the influence of heat and light is conspicuous. Both operate probably by exciting the actions of vegetables connected with their vitality ; and from the change to which solar light gives rise in the reciprocal action between the growing plant and the atmosphere, it is obvious, that it also in part acts as a chemical power. Its influence is well marked in the changes which plants suffer when they are secluded from light ; they become of a pale colour, which soon changes to green when the light is admitted. This action is principally exerted on the sap circulating through the leaves, and it is accordingly at the margin of the leaf that the change of colour first appears.

Such are the circumstances most materially influencing vegetation ; and considering the operation of all of them, the following may be presented as the theory of the process which the present state of our knowledge suggests. Regarding germination as its first stage, the seed exposed to atmospheric air expands ; and the farinaceous matter, by the action of the oxygen of the air, is converted into sugar, which serves as food to the infant plant. Its organs are gradually unfolded, and its nourishment received from a different source ; water, pure, or holding vegetable and animal matter in solution, is absorbed by the roots ; and, in a soil containing decomposing vegetable and animal matter, different aërial fluids are received, and mingle with the sap. This, in its progress through the root, dissolves even part of the vegetable matter ; and from



this, the plant, in the first stages of its growth, is better enabled to form its products. It is brought to the leaves of the vegetable, and presented under an extensive surface, covered with a very thin membrane, to the action of the air and light; part of its water transpires; carbonic acid, and other elastic fluids from the atmosphere, are perhaps absorbed; and by the action of the vessels, assisted by the chemical agency of light, new combinations are established, and the proper juice of the plant is formed. This is conveyed by the footstalk of the leaf, and by vessels proceeding downwards through the bark, or between it and the wood: it is deposited in different parts, or is still farther changed in its progress,—changes from which the peculiar vegetable products are formed.

From the substances conveyed to the plant from the air, water, and soil, must be derived the elements of which its products are formed. But in the uncertain state of our knowledge with regard to what principles are truly elementary, it is perhaps in vain to attempt to trace the source of those principles which the vegetable analysis affords. There are found in the products of the vegetable kingdom, though in very different proportions, oxygen, hydrogen, nitrogen, carbon, sulphur, phosphorus, the fixed alkalis, lime, magnesia, alumina, and silex, and several metals, particularly iron, manganese, and, as it has likewise been affirmed, gold. With regard to oxygen and hydrogen there is no difficulty, as these are abundantly supplied from water. From a common soil, containing always vegetable and animal matter, carbon may be derived; but in plants growing merely in water and air, there is the difficulty, if we do not admit of the absorption of carbonic acid from the atmosphere, of accounting for the origin of the carbon necessary to their growth, and still more for the larger quantity disengaged



in the state of carbonic acid, when the plant is not under the action of light. Nitrogen, if it is not a compound body, may be derived from the atmosphere. With regard to the saline, earthy, and metallic substances present in more sparing quantity, they may in general be derived from the soil; and the researches of Saussure have established some important facts in proof of this. It appears, however, from some experiments, that they may sometimes be derived from the atmosphere, being probably deposited in the state of atmospheric dust on the leaves of the plants, and absorbed. This serves to explain the results of some experiments by Schrader, in which a portion of saline and earthy matter, exceeding what was originally present in the seeds, was obtained from wheat, rye, and other similar plants, which had grown in pure flowers of sulphur, and been supplied only with distilled water; as in these experiments the atmospheric air was freely admitted. Some plants have a disposition to fix a considerable portion of earthy matter in their composition: thus, wheat, oats, and many of the hollow grasses, have an epidermis containing a large proportion of siliceous earth. Sometimes silex is deposited in the internal parts, as if by a secretion, and considerable masses have thus been found in trees. The Tabasheer of the bamboo is an instance of this.

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CHAP. II.—OF THE PROXIMATE PRINCIPLES OF VEGETABLES.

THE products of vegetation are extremely diversified; but in submitting them to chemical arrangement, they are reduced to a few species, named the Proximate Principles of Vegetables. These exist in the different parts of plants,



and in their products, either insulated, or in states of mixture or combination ; and, in the latter case, are separated by processes founded on their chemical relations, as by the action of different solvents, or by the application of heat. If the leaves of a plant, for example, are macerated with water, the entire substance is not dissolved, but they may yield a matter soluble in water ; if distilled, a volatile principle may be procured ; if macerated in alcohol, a portion of matter may be extracted, which the water had not dissolved : and by multiplied operations of this kind, a number of distinct substances are obtained.

The diversities of properties in these principles, and from which the discrimination between them is established, arise from differences in their chemical constitution. Still they have all the general characters of vegetable matter, and in their analysis afford similar products, diversified principally in the proportions.

This analysis is effected in various modes. The most general is the analysis by heat. When a vegetable substance is exposed to a temperature superior to  $212^{\circ}$ , after the superfluous water is dissipated, its decomposition commences, from the re-action of its elements, and the new combinations into which they pass. A dark-coloured empyreumatic oil distils over with a portion of an acid liquor ; carbonic acid, carbonic oxide, and carburetted hydrogen gases are disengaged, sometimes also ammonia is produced, and a quantity of charcoal remains, frequently containing portions of saline, earthy, or metallic matter. These products are not those which existed in the vegetable matter, but are compounds, arising from the decomposition of the proximate principles, and the union of their elements in new modes and proportions. The oil is produced by the union of part of the hydrogen with part of the carbon of the vegetable matter ; the acid, from the



combination of another portion of carbon and hydrogen with oxygen; the carbonic acid, oxide, and carburetted hydrogen, are similar products; the ammonia is formed by the combination of nitrogen which may exist in the substance with hydrogen; and the remaining charcoal arises from the excess of carbon not spent in the formation of these compounds.

From such an analysis, however, little is learned of the nature of the matter subjected to it; for although the products can be collected, and their composition may be ascertained, yet experiments of this kind are liable to sources of error nearly inappreciable. From slight variations in the state of the matter analysed, with respect to humidity, or from still slighter variations of temperature in conducting the experiment, important differences in the results will be produced; and we are likewise unable to ascertain what quantities of the products of the analysis have pre-existed in the vegetable matter, or have been actually formed. We acquire, therefore, only some general information. If much acid has been afforded by the analysis, we conclude that the matter analysed has contained a large proportion of oxygen, as this principle enters so largely into the composition of acids. If much oil has been obtained, we conclude, by a similar mode of reasoning, that hydrogen has been an abundant element of the matter analysed. From the production of ammonia or prussic acid, we infer the existence of nitrogen: from the quantity of charcoal, we draw some conclusion as to the quantity of carbon existing in the vegetable; and by burning this charcoal, we discover the quantities and kinds of earthy and metallic matter which it has contained.

Sometimes vegetable substances are analysed, by heating them in contact with atmospheric air, so as to excite combustion; and from the products, determining the na-



ture and proportions of the constituent principles. Certain principles can likewise be analysed by subjecting them to spontaneous decomposition, as saccharine matter, for example, by the process of fermentation: and, lastly, vegetable analysis may in some cases be effected by the agency of the nitric acid, which produces oxygenation of the vegetable matter, and by the products indicates the principles of which it has been formed.

Another mode has been introduced by Gay-Lussac and Thenard, of analysing the vegetable products,—mixing a given weight of the vegetable matter, with a certain quantity of some substance containing oxygen, in so close a state of combination, as to yield it to these principles when strongly heated with them, and thus causing the mixture to burn slowly in an apparatus adapted to collect the products over mercury. In this way all the carbon in the vegetable matter is converted into carbonic acid, and the hydrogen into watery vapour, which are collected and estimated. The substance which they at first employed in this method was the chlorate or hyper-oxy-muriate of potash; but this is liable to the disadvantage of being itself decomposed by the heat, and forming ærial products, which mix with those from the vegetable body. The peroxide of copper also proposed by them is now generally substituted, and is well adapted for the purpose, as it will not alone yield oxygen even when strongly heated, while it readily affords oxygen to any inflammable matter with which it is heated. Hence, by weighing the oxide before and after the analysis, we obtain the quantity of oxygen which has been expended, and by comparing this with the quantities of carbonic acid, and of water produced, we learn the proportion of carbon and hydrogen which existed in the vegetable substance. The peroxide of copper contains only a small quantity of oxygen com-



pared to its weight, consisting of 64 parts of copper and 16 of oxygen, hence it is necessary to employ a large proportion of it. The simplest method of conducting the analysis is to dry the vegetable matter as thoroughly as possible, by placing it in a fine powder under an exhausted receiver along with sulphuric acid, at the same time raising it to the temperature of  $212^{\circ}$ , as in the apparatus contrived by Dr Prout, (*Ann. of Philosophy*, vi. 272); then to mix it with peroxide of copper in the proportion of 3 or 4 grains to 150 or 200 of the peroxide, and apply heat to the mixture in a copper or glass tube, by means of a spirit lamp. To ascertain the quantity of hydrogen, the gaseous products are transmitted through a tube filled with fragments of dried chloride of calcium; the watery vapour is absorbed by these, and its quantity is of course indicated by their increase of weight: of this increase, every nine parts denote one of hydrogen. The elastic products which pass through the tube are to be collected over mercury, and will consist either of carbonic acid, or carbonic acid mixed with nitrogen. To estimate these, a solution of potash is introduced, which absorbs the carbonic acid, the quantity of which is thus indicated by the diminution of volume; the remaining volume shows the quantity of nitrogen which may have existed in the substance analysed. From the quantity of carbonic acid the proportion of carbon is easily estimated, being 6 parts out of every 22, by weight, of that acid gas. Sometimes the carbon escapes, without being fully oxygenated, in the state of carbonic oxide, and increases the bulk of the residual nitrogen. If this is suspected, the gas must be mixed with a portion of hydrogen and oxygen gas, and fired by the electric spark. It has been stated, that the nitrogen is itself sometimes oxygenated by the peroxide of copper: to remedy this, it has been proposed to repeat the analysis with protoxide of copper.



In this way the quantities of carbon, hydrogen and nitrogen, if it be present, are determined; but oxygen also is a very general ingredient of vegetable substances. To estimate its amount, the quantity of it in the water, and carbonic acid obtained, is compared with the loss of weight of the peroxide of copper. If they agree, no oxygen can have existed in the vegetable: usually the loss of weight of the copper will be less than the calculated quantity of oxygen in the products: this deficiency indicates the oxygen that had been present in the body. It is obvious, that if the analysis has been correct, these different quantities added together ought to be equal to the original weight of the substance. If the vegetable matter to be analysed is in the liquid state, it may be made into a paste with the peroxide of copper, and subjected to a similar process. If it is volatile, its vapour is conducted over a known weight of the peroxide ignited in a glass tube. The peroxide of copper employed in these methods may be obtained by calcining nitrate of copper at a red heat, or by calcining filings of the metal in a muffle.

This, though the simplest and best method of analysing vegetable or animal substances, is yet liable to sources of fallacy, which render it difficult to attain accuracy in applying it. Much necessarily depends upon the subjects of analysis being perfectly dried, otherwise the adventitious water will render the results incorrect; yet to effect this without decomposing the body by the heat applied is extremely difficult, and in few cases, indeed, can it be perfectly performed. The presence of atmospheric air in the tubes is also productive of error, from the intermixture of nitrogen to which it gives rise. With regard to the peroxide of copper, too, Dr Prout has stated two objections, one that it is liable to absorb hygrometric water when exposed to the atmosphere, and secondly, that, like many other pow-



ders, it condenses air in its pores. These circumstances, with the complicated nature of the products, render the analysis of organic bodies one of the most delicate operations in chemistry, and there are even yet but few results obtained by it which can be fully depended on.

Gay-Lussac and Thenard have deduced from their analyses some important general conclusions. 1st, It is found, that in a number of vegetable products the proportions of oxygen and hydrogen are those which form water, to which a portion of carbon is added; such substances are neither acid nor resinous, but are analogous to sugar, gum, starch and ligneous fibre. 2d, A number of other substances contain a larger proportion of oxygen than what is sufficient to convert all their hydrogen into water; these, it is affirmed, are always of an acid nature, as tartaric or citric acid. 3d, A third class of bodies contain less oxygen than what is equivalent to the hydrogen they contain; these, it is stated, are either resinous, oily, or analogous to alcohol. To these principles laid down by Gay-Lussac there are, however, not a few exceptions; thus, the benzoic and gallic acids, and it has been lately affirmed, the acetic acid, contain no excess of oxygen. No reference, moreover, is made in them to the nitrogen, which many vegetable substances are now known to contain. There are, however, a number of substances to which they do apply, as is obvious from the following table of the composition of various vegetable proximate principles, as determined by the experiments of Gay-Lussac, Berzelius, Dr Prout, Dr Ure and others.



Substances analysed.	Carbon.	Oxygen.	Hydrogen.	Supposing the oxygen and hydrogen in the state of water in the substance.		
				Carbon.	Water.	Oxygen in excess
Sugar, . . . . .	40	53.34	6.66	40	60	0
Gum-arabic, . .	42.23	50.84	6.93	42.23	57.77	0
Fecula, . . . . .	43.55	49.68	6.77	43.55	56.45	0
Sugar of milk, .	38.825	53.834	7.341	38.825	61.175	0
Oak-wood, . . .	52.53	41.78	5.69	52.53	47.47	0
Beech-wood, . .	51.45	42.73	5.82	51.45	48.55	0
Mucous acid, . .	33.69	62.67	3.62	33.69	30.16	36.15
Acetic acid, . .	48	48	4	48	36	16
Succinic acid, .	do.	do.	do.	do.	do.	do.
Tartaric acid, . .	36.36	60.60	3.03	36.36	40	23.23
Citric acid, . .	41.38	55.173	3.483	41.38	31.03	27.58
						Hydrog. in excess.
Benzoic acid, . .	75	20	5	75	22.5	2.5
Gallic acid, . . .	56.64	38.36	5	56.64	43.155	.205
Resin, common,	75.94	13.34	10.72	75.94	15.16	8.9
Copal, . . . . .	76.81	10.61	12.58	76.81	12.05	11.14
Wax, . . . . .	81.79	5.54	12.67	81.79	6.3	11.91
Olive oil, . . . .	77.21	9.43	13.36	77.21	10.71	12.08
Alcohol, . . . .	52.17	34.79	13.04	52.17	39.14	8.7
Ether, . . . . .	65	21.62	13.5	65	24.3	10.8

The proximate principles of vegetables have been reduced to the following species: Mucilage or Gum, Fecula, Sugar, Gluten, Albumen, Caoutchouc, Jelly, Fixed Oil, Volatile Oil, Camphor, Wax, Resin, Extract, Tannin, Ulmin, Ligneous Fibre, Vegetable Acids, the principles termed Vegetable Alkalis, Morphine, Emetine, Strychnine, Cinchonine, Quinine, &c. To these have been added some principles more subtle, or more doubtful, as the Aroma, Bitter and Acid Principles, and Colouring



Matter. Besides these, some principles have been enumerated, the peculiarities of which seem to arise from intermixture, as Inulin, Asparagin, &c.

SECT. I.—*Mucilage, or Gum.*

THIS is one of the most abundant proximate principles of vegetable matter, and it seems to be the first product of the changes which the sap suffers from the action of the vessel. It is found in all young plants, in their roots, stalks, and leaves, and particularly in their seeds; and it is often present in such large quantity in their vessels as to be discharged by spontaneous exudation. It is also frequently combined with other proximate principles, from which it may be separated; but its characters are best taken from those varieties of it in which it exists in a pure form.

Pure gum obtained by exudation is concrete, brittle, and semi-pellucid, of a white, yellowish, or reddish colour. It is inodorous and insipid, neither fusible nor volatile, and not inflammable in the strict sense of the term, for although it is charred when heated under exposure to the air, it scarcely burns.

Gum is soluble in water, either cold or warm, in every proportion, forming a thick and adhesive solution, from which the gum may be obtained by evaporation in its original state. This solution is named Mucilage in pharmacy. It becomes sour on being long kept, but cannot, even by the addition of yeast, be made to ferment.

A chemical character serving to distinguish gum, is its perfect insolubility in alcohol; it is even precipitated by this re-agent from its watery solution. It is likewise in-



soluble in ether, or in oils; but triturated with oils, it diffuses them in water.

Gum suffers decomposition from the more powerful acids. Sulphuric acid chars it, causing at the same time a formation of water and acetic acid. Nitric acid causes the formation of oxalic, malic, and saccho-lactic or mucic acids, in proportions varying according to the concentration of the acid. Chlorine converts it almost entirely into citric acid. The alkalis and alkaline earths, in solution in water, dissolve gum without producing on it much change. Some of the earthy and metallic salts give rise to changes which serve to distinguish it; in particular, the subacetate of lead throws down a copious white precipitate from its solution, while the acetate has no sensible effect on it. The precipitate consists, according to Berzelius, of 38.25 parts of oxide of lead, and 61.75 of gum. It has been termed, in contradiction to all rules of chemical propriety, *gummate of lead*. Sulphate of iron converts gum into an orange-coloured jelly; a solution of silex in potash renders it opaque.

Gum is decomposed by heat, affording a large quantity of empyreumatic acetic acid, which was formerly supposed to be a peculiar acid, called from its origin Pyromucous: with this are produced empyreumatic oil, carbonic acid, and carburetted hydrogen gases, ammonia, and a residuum of charcoal, which affords a little phosphate of lime. The principal elements of these products are carbon, hydrogen, and oxygen; and from the large quantity of acid produced, the proportion of oxygen may be inferred to be large. In the preceding table the proportions are given as found by Gay-Lussac, which are not very different from those assigned by Berzelius. Dr Thomson, from the analysis of the compound of gum and oxide of lead, has inferred the equivalent of gum to be



90, conceiving it to consist of six atoms of carbon, 36, six atoms of oxygen, 48, and six of hydrogen, 6, = 90. The production of ammonia is supposed to arise from impurity. The lime of the residual charcoal is capable of being discovered by tests in gum itself, being precipitated in particular from its solution by oxalic acid. It is from the presence of lime that gum appears to be incapable of passing into the vinous fermentation, this earth counter-acting that process; and it is this chiefly which distinguishes gum from fecula, another proximate principle of vegetables, to which it has a great resemblance.

The purest gums are obtained by spontaneous exudation; such are the gum-arabic, and the cherry-tree and plum-tree gum. Gum tragacanth differs a little from pure gum, particularly in being imperfectly dissolved by cold water, though with boiling water it forms a very viscid solution; it is also not precipitated by silicated potash. The mucilages extracted by the maceration of water on seeds and roots which abound in gummy matter, scarcely form transparent solutions, and they also present some appearances with re-agents different from pure gum.

Gum, in the state of mucilage, can be extracted in considerable quantity from a number of indigenous plants, by maceration of their roots in water, and a supply of it has thus been procured for several purposes in the arts, particularly in calico-printing. It has thus, in particular, been extracted from the root of the blue-bell. By a slight preparation, too, it may be obtained from the greater number of the lichens, these being freed from the outer skin, by soaking for some time in boiling water; then boiling strongly in water, to which a small quantity of carbonate of potash has been added, and reducing the mucilaginous liquid by evaporation to the requisite consistence.

Gum is used in pharmacy to suspend oils, balsams, and



resins in water ; and in several arts is employed, from its adhesive quality.

## SECT. II.—*Of Fecula, or Starch.*

THE principle distinguished by this name, forms the principal part of the nutritive grains and roots, and is extracted from them by the action of water, the grain or root, after being cleansed, being bruised, and beat with the water ; the fecula is extracted in the state of a powder, which is diffused through the water, and subsides. Starch is the fecula of wheat, and is extracted by a process of this kind ; a brilliant whiteness being given to it by allowing the liquor to become acescent, and then digest on it : and other varieties of it are obtained from rye, from the potatoe, and from the roots, stems, and seeds of a number of plants. It is sometimes extracted, quite mild, from poisonous or acrid plants, the acrid matter being dissolved by the water, and thus abstracted.

Fecula is usually in the form of a light white powder, very soft and smooth to the touch, and apparently composed of impalpable brilliant grains ; it is insipid and inodorous, though it sometimes has colour and taste, from other principles which adhere to it.

The property characteristic of this principle is insolubility in cold water, while it is soluble in hot water, forming a solution viscid or gelatinous. The solution of it takes place when the temperature is raised to 160° or 180° ; and if the water is dissipated by evaporation, the solid matter is soluble as before. In drying, it assumes a structure somewhat regular, dividing into six-sided columns. It is insoluble in alcohol and ether, and alcohol precipitates it from its watery solution. It is also preci-



pitated from its solution by subacetate of lead, and nitromuriate of tin, but not by silicated potash, a property in which it differs from gum. The best test of the presence of starch is iodine, which, it has been mentioned, immediately form with it a blue coloured compound. A sub-iodide may also be obtained of a white colour, which is rendered black by acids. From the researches of Gay-Lussac, starch appears to consist of 43.55 of carbon, 49.68 of oxygen, and 6.77 hydrogen. These proportions, it will be found, are not very different from those constituting sugar. Hence the conversion of starch into sugar is a change which not unfrequently happens. It happens, for instance, in germination, as is exemplified in the process of malting already described. The starch in the barley is found to be in a great measure converted into sugar. Proust, indeed, has affirmed, that a large proportion of barley is composed of a peculiar principle which he has termed *hordein*, and that the process consists chiefly in the change of this hordein into sugar, and partly into starch. Dr Thomson, however, is of opinion, that this supposed principle is merely a modification of starch. It is from this property of starch that the different nutritive grains form fermented liquors, for previous to its change into sugar it will not ferment. A similar conversion into sugar is produced in some vegetables by the action of frost.

Fecula is capable of passing into the vinous fermentation, and of undergoing the previous change of conversion into saccharine matter. This happens in the process of the germination of seeds, and it is from this property that the different nutritive grains form fermented liquors. It can even be more directly and completely converted into sugar. The process first given by Kerchoff consists in diluting one part of sulphuric acid with 200 of water, causing this to boil, and adding to it gradually 100 parts of



starch diffused in 200 of water, continuing the ebullition for 36 hours, and adding water to supply the evaporation ; a little charcoal is then added, and lastly chalk, to neutralize the acid. A syrup is obtained by evaporation, from which sugar may be crystallized. In this process, it has been proved by Saussure, no gaseous matter is evolved, the quantity of sulphuric acid remains unchanged, and the weight of the sugar is greater by a tenth than that of the starch from which it is produced. By a careful analysis of each, he found that the chief difference was, that the sugar contained more water, or more oxygen and hydrogen, than the starch. Hence, it may be inferred, that the elements of the latter simply united in the process with additional portions of oxygen and hydrogen, and thus produced sugar. Starch sugar has the properties of saccharine matter, but is inferior in sweetness, and is less soluble in water ; it is capable of fermenting ; a little gum is formed with it ; and it assumes the form of spherical grains.

Fecula is decomposed by heat, blackens, and forms at length a spongy charcoal, and if heated strongly, burns. Its ashes give traces of phosphate of lime. The acids decompose fecula with results somewhat similar to those which they produce on gum. Sulphuric acid chars it, and forms water and acetic acid. Nitric acid heated with it converts it into malic and oxalic acids. The alkalis appear to dissolve it, as their solutions reduce it to the consistence of a jelly, even without the aid of heat. Starch combines with tannin, forming a flaky precipitate, which is dissolved at a temperature of  $120^{\circ}$ , and re-appears on cooling.

Fecula, in a number of its properties, bears a resemblance to gum, and still more to the mucilages extracted by maceration from the seeds and roots of plants, and it



is probably formed from mucilage in the process of vegetation. It forms the principal part of the nutritive seeds and roots, and is itself highly nutritious; hence it is used in its pure state as an article of diet, sago, arrow-root-powder, sago and cassava being varieties of it, the two latter somewhat modified by heat. Wheat affords it in larger quantity than any other vegetable, and in a state of perfect purity. The root of the potatoe also affords a large quantity of it, and the starch of both these vegetables is used for the adhesive property of its gelatinous solution.

Amidine or Amyline is a modification of starch, approaching more in properties to gum, particularly in being, to a certain extent, soluble in cold water. It is formed from the action of heat on starch; thus, if starch is kept for some time exposed to the air at a temperature of  $212^{\circ}$ , it becomes of a reddish tint, and is afterwards soluble in cold water. It still retains the property of producing a blue colour with iodine. It is supposed by some that starch becomes amidine when it is acted on by hot water. Saussure obtained amidine by exposing a paste of starch and hot water for a long time to the air: it has been conjectured, that the amidine was rather produced at first by the action of the hot water. When starch is more strongly heated, or when it is boiled for a long time, it suffers a greater change, becomes still more soluble in water, and gives a purple tint with iodine.

### SECT. III.—*Of Jelly.*

THE juices of certain fruits, as the currant, if not too watery, concrete into a kind of tremulous jelly. The substance communicating this property is very sparingly soluble in cold water, while it dissolves easily in boiling wa-



ter, the solution as it cools becoming gelatinous. In this character it resembles fecula. It is usually accompanied by some vegetable acid. When rendered solid by evaporation, Vauquelin found it to be transparent. It is dissolved by the alkalis and dilute acids. Nitric acid converts it into oxalic acid, without disengaging from it any nitrogen. It is precipitated by infusion of galls.

It is from the presence of this principle, that the juice of the currant and other fruits form a jelly when prepared with sugar. To form the gelatinous consistence, it is necessary that there should be a certain proportion between it and the water; by long boiling too the property is lost. Hence the reason, as Vauquelin has remarked, that in preserving the preserved jellies of these fruits, if the juice is too watery, or the proportion of sugar not sufficiently large, so that it is necessary to continue the boiling long, the gelatinous consistence is not acquired. It is supposed that jelly is merely a modification of mucilage, probably in union with some acid.

#### SECT. IV.—*Of Sugar.*

SUGAR is an abundant vegetable product, mixed frequently with other principles, but often also secreted in a more pure form. It thus exists as the chief constituent part of the sweet juices of many fruits; and there are plants, as the sugar-cane, *Arundo Saccharifera*, and the sugar-maple, which afford it in large quantity. From both of these it is extracted, and even from other plants, for the uses to which it is applied.

The juice of the sugar-cane, at a certain state of maturity, is highly saccharine. It is expressed and boiled, a



quantity of lime being added, the operation of which appears to be that of neutralizing a portion of oxalic acid in the juice, which prevents the concretion of the sugar. The juice, after the proper decoction, is allowed to remain at rest, until it become clear, is boiled down in another vessel, until, on cooling, the sugar separates in a concrete state, a sweet liquor remaining, Molasses or treacle, which is drained off. The saccharine matter thus obtained, being not altogether pure, is purified by boiling its solution in lime water, with the addition of a quantity of blood; the lime neutralizing any acid that may be still present, the blood coagulating, and the coagulum entangling the impurities, and rising to the top when it is removed. The liquor, after being sufficiently concentrated, is drawn off, and run into inverted conical moulds of clay, in which it becomes concrete; the base of the inverted cone is then covered with clay which is moistened with water, and this filtrating slowly through the mass, removes any dark coloured saccharine liquor which may have remained; the purified white mass is afterwards strongly dried. By a similar process, sugar is obtained from the juice of the sugar-maple; and from the juice expressed or extracted by decoction from the roots of the Beet, Parsnip, and some similar plants. Sugar from the juice of the grape differs somewhat from common sugar; and, according to Saussure, is similar to the sugar artificially prepared from starch. Sugar is also a product of the animal system, being obtained in several secretions, both in a healthy and morbid state.

Sugar, when pure, has a sweet taste, free from any peculiar flavour; it is of a white colour, and appears in the mass to consist of brilliant grains. By fixing threads in syrup, which is allowed to evaporate in a warm room, sugar may be obtained in transparent rhomboidal crystals.



They contain, according to Berzelius, 5.6 *per cent.* of water. Pieces of sugar when rubbed together are phosphorescent. When pure, it suffers little change from the atmosphere; raw sugar is deliquescent from impurity.

Sugar is soluble in water; at the temperature of 50 of Fahrenheit it does not require much more than an equal weight. Boiling water dissolves nearly any quantity of it. Its solution is more or less viscid. Sugar is also soluble in alcohol; this solution, when concentrated by evaporation, affords large crystals.

When exposed to heat, sugar is blackened, swells up, and burns to a coal; if the heat is strong, its combustion is attended with flame. The products are carbonic acid and water. Exposed to heat in close vessels, it yields a considerable quantity, rather more than half its weight, of weak empyreumatic acetic acid, a small quantity of empyreumatic oil, with carbonic acid, and carburetted hydrogen gases, the residuum being charcoal. These products indicate that sugar consists of carbon, hydrogen, and oxygen. From the experiments of Dr Prout, it is inferred that sugar consists of 40 of carbon, 53.34 of oxygen, and 6.66 of hydrogen; that is, of 5 atoms of each ingredient, which will give 75 for its equivalent. By boiling sugar with oxide of lead, Berzelius obtained a compound, to which he gave the improper name of Saccharate of lead, from the constitution of which, he inferred the equivalent of sugar to be 81; this would indicate it to consist of 6 atoms of charcoal, 36, 5 atoms of oxygen, 40, and 5 of hydrogen, 5. If the first supposition is adopted, sugar may be conceived to be composed of equal volumes of vapour of carbon, and watery vapour.

By the abstraction of oxygen, sugar is converted into a substance somewhat similar to gum, a change produced in it, in some experiments by Cruickshank, by the action



of phosphuret of lime. The opposite process of the conversion of fecula into sugar has been already noticed.

Sugar is decomposed by the acids. Sulphuric acid causes an evolution of charcoal. Nitric acid is rapidly decomposed by yielding oxygen, and an acid is formed, the same with one which exists native in vegetables, the oxalic acid, a smaller portion of another, the malic, being also frequently produced. Liquid chlorine converts it into citric acid. The alkalis form combinations with sugar, in which the sweet taste is lost, though it is restored when the alkali is neutralized by an acid. The compound, it is singular, is not soluble in alcohol, though both its ingredients are. The action of the alkaline earths is similar, and both lime and strontites are rendered more soluble in water by the combination. These compounds have a bitter astringent taste, and their solutions are viscid and tenacious, similar to a solution of gum. A solution of unrefined sugar kept for some time suffers spontaneously a similar change, probably from the action of a little lime adhering to it.

Sugar being highly nutritious, is, independent of its sweet taste, of importance as an article of diet. Its solution, Syrup as it is named, is employed in pharmacy; and it enters into the composition of ink, and of some pigments and varnishes, to give them a degree of lustre.

MANNA is a concrete saccharine juice, obtained from several plants, but principally from some species of Ash. It appears to differ chiefly in containing a portion of extractive or mucilaginous matter with which the sugar that is its basis is mixed. It has been said, however, to owe its qualities to a peculiar principle termed Mannite, which differs from sugar in not being disposed to ferment, even when yeast is added to its solution.



HONEY is another vegetable product, similar in many of its properties to sugar; nor has any essential difference been pointed out between them, except the natural fluidity of honey, and perhaps its viscosity. A species of sugar can be obtained from honey by the action of alcohol, or by clarifying it by a moderate heat, and the action of carbonate of lime. This sugar does not crystallize so readily as common sugar, and it suffers changes somewhat peculiar from the alkalis and earths, effervescence being produced, and a brown or black colour acquired. Honey itself is converted, like sugar, into oxalic acid by nitric acid.

Honey is formed in the flowers of plants, and is always exposed, frequently by a very complicated organization, to the atmospheric air. It has been supposed to be designed to receive and retain the fecundating pollen from the male parts of plants, as its secretion diminishes or ceases when the fecundation is completed. A number of insects feed upon it, and it is collected in large quantity by the bee.

The saccharine matter formed in certain morbid states of the animal economy, giving rise to the disease named Diabetes, is similar in properties to the sugar of honey.

#### SECT. V.—Of *Gluten*, *Albumen*, *Caoutchouc*, &c.

IN the analysis of the flour of wheat by the affusion of water on the paste kneaded in the hand, the saccharine and mucilaginous matter is dissolved, and the fecula is carried off diffused in the water; there remains a viscous elastic substance, which, from its resemblance in some properties to an animal product named Gluten, has obtained the name of Vegetable Gluten. It amounts, in the humid state in which it is obtained, to from a third to a fifth part of the weight of the flour. It appears to be



more abundant in the wheat of warm than of cold climates. In the other nutritive grains, it is contained in much smaller quantity, and in some of them, as well as in the nutritive roots, there are no traces of it. It appears, however, to be contained in the expressed juices of some plants.

Gluten, combined with water in the state in which it is obtained from the flour of wheat, is soft and ductile, fibrous in its texture, and highly tenacious and adhesive; it is elastic, so that it can be stretched out to great length; but when the stretching force is withdrawn, speedily shrinks into its former dimensions. It is of a greyish colour, and has scarcely any odour or taste. It is insoluble in alcohol and in water; by long digestion, however, it is partially dissolved by the latter.

By a moderate heat, the water contained in gluten in this state is dissipated; it becomes hard and brittle, and may then be preserved for a long time unchanged. But soft gluten soon passes into a state of fermentation, and afterwards of putrefaction, similar to that which animal matter suffers; and there is a formation of ammonia, acetic acid, and an oily matter. Fermented gluten is dissolved by alcohol, and this solution forms a flexible varnish.

The acids act on gluten. The weaker acids dissolve it without producing in it much change. Sulphuric acid chars it, and causes an evolution of carburetted hydrogen, and formation of ammonia and acetic acid. Nitric acid disengages from it nitrogen gas, and forms oxalic and malic acids. Gluten is dissolved by the alkaline solutions, aided by heat, suffering also a change in its properties from partial decomposition, so as to form a kind of soap.

This principle is decomposed by heat, and the products yielded by this decomposition are very similar to those from animal substances. A large quantity of carbonate of ammonia is formed, with empyreumatic oil, and a little



prussic acid; carburetted hydrogen gas is disengaged, and there is a residuum of charcoal. The production of ammonia indicates the predominance of nitrogen in its composition: the large quantity of oil farther indicates the presence of hydrogen in considerable proportion, while, from no acid being produced, it may be inferred to contain little oxygen. Phosphorus appears to exist in it in small quantity.

Gluten thus appears to be analogous in composition to animal matter. Hence it adds to the nutritive quality of the grains in which it exists, and to this, in part, is to be ascribed the superiority of wheat. It communicates also that superiority which bread prepared from wheat has to that from other grains; as the flour of wheat made into a paste with water, forms from the presence of gluten a ductile mass, which, when rendered porous by the disengagement of carbonic acid, from the slight fermentation excited by the action of the leaven, remains after being baked, light and spongy, while the flour of other grains does not undergo this change, but forms rather friable pastes. It appears to promote the acetous fermentation, and a solution of sugar macerated on gluten is very soon converted into vinegar.

M. Taddey, an Italian Chemist, has lately discovered, that gluten may be separated into two distinct principles, one of which, Gliadine, (from *γλιν*, gluten,) is procured by acting on the gluten repeatedly with alcohol. The gliadine is dissolved, and by evaporation is obtained in the state of a yellowish coloured substance of a sweet balsamic taste. It is, in some respects, similar to the resins, but differs from them in being insoluble in ether. It is not soluble in water, but is dissolved by warm alcohol, being in great measure deposited, when the solution cools; from the alcoh-



lic solution, it is also precipitated by the addition of water. It is dissolved by acids and alkalis. Placed on burning coals it burns with a bright flame; it suffers fermentation, and induces the same process in saccharine substances. The other principle of the gluten, which is not dissolved by the alcohol, is called Zimoma, (from ζυμη, a ferment). It is a hard tough mass of an ash colour; it is heavier than water; insoluble in water and alcohol, but is dissolved by acids at a boiling temperature. It does not ferment, but causes other bodies to ferment. It is liable to putrefy, when it exhales an ammoniacal odour; it forms a kind of soap with potash; at a high temperature it burns with a smell like that of burnt hair. It is remarkable for producing a rich blue colour when mixed with powdered guaiac, a singular phenomenon, of which the cause is unknown, but appears to be in some manner connected with oxygenation, as it does not happen when the atmospheric air is excluded. This effect is produced in a less degree when guaiac is kneaded with flour and water; it is not caused by starch, and is faint when the flour contains little gluten; hence, it has been proposed as a test of the quality of flour, by indicating the proportion of gluten in it.

FROM the juices of certain plants, chiefly of the cruciform kind, a flocculent substance separates by coagulation when they are heated; it is also coagulated by the action of acids. These properties being analogous to those of animal albumen, this substance has been called Vegetable Albumen. It is now known to be merely a variety of gluten, somewhat altered by the process by which it is obtained. There does, however, exist a vegetable albumen, which has almost all the properties of animal albumen, which, of all the varieties of vegetable matter, ap-



proaches most nearly in its characters to animal substances. It was obtained by Vauquelin from the juice of the *Carica Papaya*, a native of the Isle of France. It is coagulated by heat, by acids, and by alcohol; is precipitated by tannin, and by various metallic salts, and, when decomposed by heat, affords a large quantity of ammonia, and the other products of the destruction of animal matter. It has also been discovered in emulsive seeds, as the sweet and bitter almond.

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To the same family with the substances considered under this section, probably belongs the principle denominated *CAOUTCHOUC*, or elastic Gum. In physical properties it has resemblance to them, and it agrees with them in approaching in composition to animal matter.

This substance is usually imported from Spanish America in hollow balls; it is the inspissated juice of a tree belonging to the family of *Euphorbia*, the *Hœvea Guianensis*, which coagulates speedily on exposure to the air: this juice obtained from incisions is applied in successive layers over a mould of clay; is dried by exposure to the sun, and to the smoke from burning fuel; and when perfectly dry, the mould is broken, leaving the hollow ball. *Caoutchouc* is not, however, exclusively the product of this vegetable, but is afforded by a number of other plants, natives of the torrid zone, either entirely the same, or with qualities little different.

*Caoutchouc*, in its solid state, is of a close texture, distinctly fibrous, of a light brown colour, or sometimes nearly white; its elasticity is such that it can be stretched to a great extent; and on removing the stretching force, it recovers its original dimensions; its softness and pliancy are increased by heat; and by the heat of boiling water it



it is rendered so soft, that two slips newly cut and pressed closely together may be firmly united. By a greater heat it is fused, and may in that state be applied, as proposed by Mr Aitken, to the surface of steel instruments, which it will cover with a transparent film that effectually preserves them from rust.

Caoutchouc is insoluble in alcohol and in water; even when the water is boiled on it, it suffers no change but that of becoming softer. Sulphuric ether, when purified by washing with water, dissolves it, and by evaporation the caoutchouc may be recovered unchanged. From the action of the essential oils, aided by heat, solutions are obtained, which remain viscid when inspissated. The fluid now commonly used to dissolve it is the purified naphtha from coal tar, which is at the same time a cheap and effectual solvent, and which does not change its properties. This solution is employed by Mr Mackintosh of Glasgow, to give a thin covering of caoutchouc to cloth, which is thus rendered impervious to moisture. Caoutchouc is also readily soluble in cajeput oil.

Caoutchouc is decomposed by sulphuric and nitric acids, the former being partly resolved into sulphurous acid; the latter produces oxalic acid. The alkalis act on it, and destroy its elasticity.

Caoutchouc is inflammable, burning with a bright light, and much smoke. Decomposed by heat in close vessels, it affords ammonia with empyreumatic oil, shewing its analogy in composition to animal matter. The analysis of Dr Ure, indeed, gave no nitrogen, and scarcely any oxygen, stating the composition at carbon 90, hydrogen 9.12, and oxygen 0.8, which would make caoutchouc almost a pure sesqui-carburet of hydrogen. So improbable a result renders doubtful the accuracy of the analysis.

Caoutchouc, from its softness, elasticity, and impermeability to water, is applied to the formation of catheters,



bougies, and tubes for conveying gases, a slip of it being twisted round a rod, and the edges being made to adhere by pressure, when softened by maceration in warm water. Its solution in oils forms a flexible varnish.

BIRDLIME is a vegetable product, analogous in properties both to gluten and caoutchouc, and which may, without impropriety, be associated with them, as probably varieties of one species. It resembles gluten in its tenacity, its insolubility in water, and its relations to the alkalis and acids; but it is less animalized, and is therefore not liable to putrefaction. It is still more analogous to caoutchouc in tenacity and elasticity, fusibility, inflammability, insolubility in water, and solubility in ether; and there are varieties of this principle obtained from different plants, less elastic and more viscid than that from the *Hœvea*, which approach therefore closely to birdlime.

Birdlime exudes from different vegetables, but it is usually prepared from the inner bark of the holly, by boiling the bark in water, until it is softened, and then laying it in layers covered with earth and stones, when after some time it becomes viscid; it is afterwards washed, kneaded, and beat; and the paste is kept humid for several days to complete the change.

This substance has a greenish colour and slight smell; it is extremely viscid and tenacious, and can only be handled when thoroughly wet; its texture is fibrous, and has such an elasticity that it can be drawn to a great length, from which, when the external force is withdrawn, it immediately contracts. It loses its viscosity when dried, but receives it on the addition of water. Placed on burning fuel, it burns with a bright flame, and with a dense smoke.

It is insoluble in water. Ether and boiling alcohol dissolve it. Strong sulphuric acid chars birdlime, and



causes a formation of acetic acid and ammonia. Nitric acid heated on it dissolves it. Chlorine renders it white, and destroys its viscosity. The fixed alkalis decompose it, causing an evolution of ammonia, and the formation of a saponaceous compound.

#### SECT. VI.—*Of Wax.*

WAX, though usually obtained as collected by the bee, is a vegetable product. It is secreted by a number of plants, and the wax of the bee was supposed to be collected merely by that insect from the pollen of flowers,—an opinion rendered doubtful by the experiments of Huber, which prove that bees form wax when all supply of this is excluded, and when they are confined, and fed with honey or sugar alone. Still the existence of wax as a principle of vegetables is fully established. It forms the silvery down sometimes conspicuous on their leaves, flowers, or fruit. The *Myrica Cerifera*, or Wax Tree, affords in large quantity a product, forming a covering on its seeds, having all the qualities of wax; other species of myrica afford the same product, and a number of other plants afford by decoction a similar inflammable concrete. It exists, too, in some vegetable products, combined with resin.

Wax is solid and brittle, easily softened, however, and acquiring tenacity from a very moderate heat; its colour is usually yellow or greenish, but it is rendered white by exposure to the air and sun, with a slight degree of humidity, without any change in its qualities. The same bleaching effect is produced on it by chlorine.

Wax melts at  $142^{\circ}$  of Fahrenheit; myrtle wax is rather more fusible, melting at  $109^{\circ}$ ; at a higher temperature it



boils; at a red heat it is decomposed, yielding, when in close vessels, a large quantity of carburetted hydrogen gases, and leaving a small portion of charcoal. It burns with a clear and bright flame, affording water and carbonic acid. According to its analysis by Dr Ure, it is composed of carbon 80.4, oxygen 8.3, hydrogen 11.3; whence it is inferred to consist of 13 atoms of carbon, 78, one of oxygen, 8, and 11 atoms of hydrogen, 11, which will give 97 for its equivalent. It is possible, as Dr Ure suggests, that an atom of hydrogen may have escaped notice; and that, in fact, wax may be composed of 12 atoms of olefiant gas and one of carbonic oxide.

Wax is insoluble in water. Boiling alcohol dissolves about a twentieth of its weight, the greater part of which is precipitated as the temperature falls. Ether also dissolves it when boiled on it. Myrtle wax is rather more soluble than bees wax in both fluids. The acids exert little action on wax unless heated, when a mutual decomposition happens. The alkalis, when boiled in solution on wax, dissolve a portion of it, and form imperfect saponaceous compounds, soluble in warm, but sparingly soluble in cold water. These are decomposed by acids, and the wax recovered from them unchanged. The myrtle wax is more easily dissolved than bees wax. Wax combines by fusion with the volatile and fixed oils, forming compounds of intermediate consistence; these are the simple liniment ointment and cerate of the Pharmacopœias. Wax approaches to the fixed oils in almost all its properties, differing principally in its firmer consistence, its solubility to a greater extent in alcohol, and forming with the alkalis less perfect saponaceous compounds. It has been supposed by Dr John to consist of two principles; one, *cerin*, soluble in ether and warm alcohol, and fusible at  $108^{\circ}$ ; the other, *myricin*, insoluble in ether and alcohol, and less fusible.



SECT. VII.—*Of Fixed Oil.*

THERE exist two species of oil in vegetables, agreeing in the common properties of unctuousity and inflammability, but essentially different in many of their chemical qualities and relations. The one, from being capable of being volatilized without decomposition, is named Volatile Oil; the other is denominated Fixed Oil. The history of the latter is the subject of this section.

Fixed oils are generally contained in the seeds and fruits of those vegetables of which they are the products, and are formed principally at the period of maturity. They are extracted by pressure,—whence they are named *Expressed Oils*,—or in some cases by decoction with water. They are frequently impregnated with the mucilaginous or extractive matter of the plant, whence they acquire colour, odour, and taste; and if heat has been employed to favour their extraction, they acquire acrimony, and suffer even a change in some of their chemical properties. The purest oils are those expressed from the fruit of the olive, or the seeds of the almond; others less pure are extracted from lintseed, hempseed, and the seeds of other plants.

Fixed oils are usually fluid, but of a thick consistence, and they congeal at very moderate colds; some, as palm oil, are even naturally concrete; when fluid, they are transparent, colourless, or of a yellow or green tinge, inodorous and insipid; they are lighter than water; they do not unite with water, and are very sparingly soluble in alcohol; with the exception of castor oil, which is abundantly dissolved by rectified alcohol, and of lintseed oil, which is dissolved, though more sparingly. Boiling alcohol dissolves fixed oils, in sensible quantity.



Expressed oils cannot be volatilized by heat unchanged. At temperatures below  $600^{\circ}$  of Fahrenheit, they remain fixed; nearly at that temperature, they are converted into vapour; but the oil thus condensed is altered in its properties; it has lost its mildness, and has become more limpid and volatile, a portion of carbon being likewise deposited. Transmitted through an ignited tube, oil is converted into carbonic acid and carburetted hydrogen, with a small portion of acid liquor, and a residuum of charcoal.

Exposed to a warm atmosphere, expressed oils gradually acquire a sharp taste and smell, and become thick. This change, named Rancidity, is owing to absorption of oxygen, which converts the mucilage they contain into an acid: hence it takes place sooner when the oil is exposed to oxygen gas. Drying oils, as those expressed with the aid of heat are named, do not become rancid, but, by absorbing oxygen, are rather converted into a resinous kind of matter. This property of drying may be communicated to oils by heating them in an open vessel, or by boiling them with metallic oxides, as that of lead; the oil probably receives a portion of oxygen, and the mucilage in it unites with the oxide. Fixed oils, especially the drying oils, when exposed freely to the air, absorb oxygen so rapidly, and with such an extrication of latent heat, as under favourable circumstances to take fire spontaneously. Many instances of spontaneous combustion had occurred from this cause, and in particular had been so frequent in the Russian arsenals, that at length a series of experiments was instituted to ascertain the circumstances connected with this. It appears from these, that if hemp, flax or linen cloth be steeped in lintseed oil, if it lie in a heap, and be somewhat pressed together and confined, its temperature rises, a smoke issues from it, and at



length, sometimes within 24 or 12 hours, it takes fire. The same thing happens with mixtures of oil with fine charcoal, as with lamp black wrapt up in linen. It is conjectured that many extensive fires which have broken out in cotton manufactures, and for which no cause could be assigned, must have arisen from this spontaneous inflammability of oils.

At the temperature of ignition, oil burns in atmospheric air; a large quantity of light and heat being extricated by its combustion. When the access of the air to the vapour of the oil is not complete, it burns with a black smoke; and a quantity of carbonaceous matter, which has escaped the combustion, is deposited. Hence the utility of a slender wick, which draws up the oil by capillary attraction, and, when kindled, produces sufficient heat to convert it into vapour. In a hollow cylindrical wick, as in the argands lamp, through which an internal circulation of air is established, the supply of air is more abundant, and the whole oil is consumed; the illumination therefore is greater, though there is some diminution of it from the light from the internal surface having to pass through the flame.

The products of the combustion of oil are water and carbonic acid. Hence it contains carbon and hydrogen, and it appears also a portion of oxygen. Olive oil was found, by Gay-Lussac and Thenard, to consist of carbon 77.213, hydrogen 13.340, oxygen 9.427. It may be regarded as composed of ten atoms of carbon, 60, one of oxygen, 8, and eleven of hydrogen, 11, = 79; or arranging these into binary compounds, olive oil will consist of ten atoms of olefiant gas, and one of water. According to Chevreul, fixed oil is not a pure proximate principle, but consists of two substances, *elain* and *stearin*. These will be afterwards noticed, as constituting the greater part of animal oil or fat.



Expressed oil is oxidated by a number of the acids. Sulphuric acid soon renders it black; the oxygen of the acid attracting part of the hydrogen of the oil, and causing the deposition of charcoal; and if heat is applied, a large portion of sulphurous acid is disengaged, and even sulphur is evolved. Nitric acid renders the oil thick; if heat is applied, the action is more rapid, and a yellow colour is communicated, the oil being rendered concrete. The drying oils are even inflamed. Chlorine thickens oil and renders it white.

Expressed oil combines with the alkalis, and when the combination is perfect, it forms Soap. If oil be mixed with half its weight of a strong solution of pure potash or soda, a thick white mass is formed, which forms a milky-like mixture with water. If the oil and the alkaline solution be boiled gently together, a more intimate combination is effected, and on cooling, a solid compound separates from the liquor. The soap thus prepared differs according to the purity of the ingredients. Common soap is made of animal oil, or fat; the finer soaps are prepared from olive or almond oil. Potash forms a soap which always remains soft; soda forms one that is more solid and firm. Hence either a solution of carbonate of soda, from which the carbonic acid has been abstracted by lime, is employed in the preparation; or if a solution of potash, rendered caustic by the same operation, be used, which is the common method in the preparation of the coarser soaps, there is added, towards the end of the boiling, a quantity of sea-salt, the soda of which, being in part evolved, has the same effect. The cleansing property of soap depends on its alkali; and although the detergent power of this is weakened by the combination with the oil, advantage is gained from its softness and smoothness, and from the alkali in the state of combination being less corrosive.



Soap is soluble in water, the solution being opaque, from the intermixture of particles of uncombined oil. It is also soluble in alcohol, forming a transparent solution. It is decomposed by all the acids, and by the greater number of the earthy and metallic salts, the acid combining with the alkali,\* and separating the oil. Hence spring water often decomposes it, from the sulphate of lime it contains. Ammonia forms with expressed oil a less intimate combination than the fixed oils do, as heat cannot be employed to favour the combination. The addition of a small quantity of it is employed in pharmacy to suspend oil in water. By adding an ammoniacal salt to a solution of soap, an ammoniacal soap is obtained by double affinity. It is less soluble in water than common soap, and suffers decomposition from exposure to the air.

Expressed oil boiled on sulphur forms a compound with it of a brown colour, a very fetid smell, and acrid taste. It likewise, when heated, dissolves phosphorus, forming a liquid which becomes luminous when exposed to the air.

Expressed oil promotes the oxidation of some of the metals, as copper or mercury, by the action of the air. It combines with a number of the metallic oxides. Boiled with oxide of lead, it forms a compound of a firm consistence, what is named in pharmacy Common Plaster.

A mutual action is exerted between fixed oils and several vegetable principles. Triturated with mucilage or sugar, it forms a milky mixture,—a mode of suspending oil in water sometimes employed in pharmacy.

Expressed oils, besides their use in pharmacy and medicine, form the basis of paints, being triturated with oxide of lead and the colouring matter. Combined with resins and turpentine, they form varnishes; and printing-ink is a composition of them with lamp black.



SECT. VIII.—*Of Volatile Oil.*

THE Volatile or Essential Oils are obtained usually from aromatic plants, by subjecting the vegetable matter to distillation with water. The oil is volatilized with the aqueous vapour, and is easily condensed; a small portion of it is retained in solution by the water; but the greater part separates, and may be obtained pure from the difference in their specific gravity. Being usually lighter, it collects on the surface. In some cases, as in the rind of the orange and lemon, the oil exists in distinct vesicles, and may be obtained by expression. The principal volatile oils are those of turpentine, aniseed, nutmeg, lavender, cloves, caraway, cinnamon, peppermint, spearmint, sassafras, and chamomile.

Essential oils have a pungent odour, and an acrid taste; the taste and smell of the oils obtained from different vegetables are very different; the odour is always that of the plant from which they are procured. They are generally lighter than water, but some have a greater specific gravity. They are usually fluid, and remain so even at a low temperature; but some congeal even at a very moderate degree of cold, and others are naturally concrete. They are volatilized by a moderate heat; the temperature at which they boil is however considerably above that of boiling water; thus, oil of turpentine boils at  $314^{\circ}$  or  $316^{\circ}$ .

Essential oils are very slightly soluble in water. The water acquires the taste and flavour of the oil. This impregnation is commonly obtained by distillation, the distilled waters of pharmacy being thus formed. They are much more soluble in alcohol; some of them being dis-



solved in every proportion, others in limited quantities. By distilling ardent spirit from vegetables containing much essential oil, distilled spirits are formed. They unite with fixed oils, and hence are often adulterated with them, a fraud easily detected by dropping them on paper, when the stain will disappear on being heated if they are pure; but if fixed oil is present, will remain as a greasy spot.

Exposed to atmospheric air, these oils lose their smell, are thickened, and become concrete, frequently depositing at the same time crystals of an acid resembling the benzoic. These changes are owing to the absorption of oxygen. The thickened oil approaches in its properties to resin.

When heated in contact with atmospheric air, they are more easily inflamed than the expressed oils, and burn with a brighter flame, probably from their greater volatility; the products of the combustion are water and carbonic acid, and the water is in larger quantity than from the combustion of the fixed oils. Hence they differ from the fixed oils in containing a larger proportion of hydrogen, to which, their greater volatility and inflammability are owing. Oil of turpentine, analyzed by Dr Ure, was inferred to consist of fourteen atoms of carbon, 84, ten atoms of hydrogen, 10, and one of oxygen, 8; hence its equivalent will be 102.

The essential oils are oxidated by the acids. Sulphuric acid renders them black, producing at the same time considerable elevation of temperature, and frequently a violent effervescence from the disengagement of sulphurous and carbonic acid gases. Nitrous acid communicates oxygen with such rapidity, especially if mixed with a little sulphuric acid, as frequently to inflame the oil. In some cases the acids combine with essential oils, and the acid



properties are neutralized without decomposition. With the alkalis volatile oils combine with difficulty, and the combination can only be effected by long trituration; the compound is slightly saponaceous.

Sulphur dissolves with the aid of heat in any of the essential oils; the solution has an offensive smell. Phosphorus is also soluble in them; and some of these solutions, that, for example, in oil of cloves, is highly luminous: it is still more so, if a portion of camphor is mixed with the phosphorus.

These oils unite with mucilage or sugar; and by the medium of ether may be suspended in water. They dissolve resin, camphor, and other vegetable principles.

In general they are used as perfumes, or in the practice of medicine. Some of them enter into the composition of varnishes.

#### SECT. IX.—Of Camphor.

THIS principle exists in comparatively few vegetables, principally in the aromatic plants. The camphor of commerce is extracted from the *Laurus Camphora*, a native of Japan; the wood of the trunk and branches of the tree being exposed to a moderate heat in close vessels, by which the camphor is sublimed. It is at first impure, but is purified by a second sublimation. Camphor is likewise contained in the essential oils of a number of plants, as those of lavender, marjoram, and peppermint, in considerable quantity; it is deposited from them when they are long kept, or may be obtained by slow distillation.

Camphor is solid and tenacious, of a white colour, having a strong fragrant odour, and a very pungent taste. It is so volatile, that it quickly loses weight when exposed



to the atmosphere; and at a very moderate heat it sublimes unchanged. If heated under compression it may be fused. It is highly inflammable, and burns with a dense light, much smoke, and a strong smell. Carbonic acid is formed, and a portion of what is named Camphoric Acid. From the analysis of camphor by Dr Ure, it appears to consist of ten atoms of carbon, 60, one of oxygen, 8, and nine of hydrogen, 9, = 77.

Camphor is sparingly soluble in water, so much being dissolved as merely to communicate a sensible taste and smell. It is abundantly soluble in alcohol: this solution is decomposed by the affusion of water; and if the water be added very slowly, the camphor appears in capillary crystals. It is also dissolved by the essential and expressed oils. The alkalis exert no action on camphor. Magnesia appears to act on it, as, when they are rubbed together, the camphor becomes smooth, and easily diffusible in water.

The more powerful acids decompose camphor. Sulphuric acid digested on it renders it brown, and dissolves it. When heat is applied, sulphurous acid gas is disengaged; and if the solution is diluted with water and distilled, it affords charcoal, a yellow oil, and a dark-brown product, resembling artificial tannin. The action of nitric acid on camphor is more peculiar. When a large quantity of nitric acid is repeatedly distilled from camphor, the latter suffers a complete change, and is converted into an acid, the Camphoric as it is named. This is obtained in slender crystals, which, according to Bucholz, are dissolved in 100 parts of water at 60°, and in 10 parts at 212°. Camphoric acid has no odour of the camphor; its taste is sour, slightly acrid and bitter, and it reddens the infusion of litmus. By a gentle heat it is fused and sublimed, and by a stronger heat is decomposed. It is



soluble in alcohol, and likewise in the mineral acids. It combines with the alkalis and earths, forming salts named Camphorates, none of which are of any importance. This acid resembles the benzoic in several of its properties, but differs in others, and their saline compounds are different.

Camphor, or a product analogous to it, appears to be capable of being artificially formed. By transmitting muriatic acid gas through oil of turpentine, a large quantity of a concrete matter, indistinctly crystallized, is obtained. This, which is at first of a brown colour, becomes perfectly white when washed with water; its odour and taste are the same as those of camphor, with a little of the turpentine flavour, which is, however, removed by sublimation from charcoal and lime. It is volatile and inflammable, and appears to have all the properties of natural camphor, except that it is not so easily dissolved by acids. The formation of it has been supposed to be owing to the acid causing a decomposition of the oil, combining portions of its oxygen and hydrogen so as to form water, and the remaining oxygen and hydrogen with the carbon forming the artificial camphor. It has been proved, however, that the product actually contains muriatic acid; that acid being obtained by passing it through an ignited tube. Hence Thenard concludes, that this product is merely a combination of oil of turpentine with muriatic acid; and from analogy he likewise infers that common camphor is not a pure principle, but a compound of an essential oil with a vegetable acid.

#### SECT. X.—*Of Resin.*

THIS principle, as it exists in vegetables, is often combined with gum, or with essential oil. From some plants,



however, it is obtained by exudation nearly pure; or if combined with a portion of essential oil, this may be removed by volatilization, and its characters, in its insulated form, can thus be determined.

Resins, if at first liquid as discharged by the plant, soon become concrete. They are brittle, and have a smooth conchoidal fracture, with peculiar lustre, and are usually of a yellow or brown colour. Frequently they are odorous and sapid, though others have neither taste nor smell. When rubbed they become negatively electric.

They melt at a moderate heat, but cannot be volatilized unchanged. When heated to ignition with the admission of the air, they burn with a dense flame. Heated in close vessels, they suffered <sup>de</sup>composition; from the products, they appear to consist of carbon, hydrogen, and oxygen, and, like the essential oils, contain an excess of hydrogen in proportion to the oxygen. The average proportions are 76 of carbon, 11 of hydrogen, and 13 of oxygen.

Resins are insoluble in water, and they suffer no change from the action of the air; hence their adaptation, under the form of varnishes, to prevent substances from being acted on by air and humidity. In a very humid atmosphere, however, they become soft. They are soluble in alcohol, and likewise in ether, these solutions being decomposed by the affusion of water. They are also dissolved by oils; and camphor renders them quite soft, and nearly liquid.

The fixed alkalis dissolve resins; and even when in the state of carbonates, the compounds are saponaceous. The more powerful acids decompose resins. Sulphuric acid at first dissolves it, but, continuing to act upon it, progressive changes of composition take place, tannin is formed, and ultimately the residual matter is charcoal. Nitric acid digested for some time on resins converts them



into what is called artificial tannin; no oxalic acid is produced in this action, a circumstance which occurs perhaps with no other vegetable substance.

A number of resins are employed in medicine, or in the arts,—such are copal, mastich, sandarach, lac, elemi, and those from the juice of the different species of pine. These have the same chemical properties, or with differences comparatively so unimportant, as not to require particular enumeration. A peculiarity of mastich is, that it is not entirely soluble in alcohol, and the part which remains undissolved approaches in its characters to caoutchouc, being glutinous and elastic. Copal, too, is more sparingly soluble in alcohol than the others, forming rather a kind of viscous mass. Sandarach and elemi are but partially soluble in oil. Lac is a resinous substance, containing a portion of extract, vegetable gluten, and a matter analogous to wax. The resinous juice of the pine, what is named Turpentine, contains a large proportion of essential oil. When this is drawn off by distillation, the substance named Common Resin remains.

Resins are employed in the formation of varnishes, being dissolved either in alcohol, or in essential or expressed oils. The former are named Spirit Varnishes; they dry quickly, but have the disadvantage of being liable to scale; and to obviate this, by giving a degree of tenacity, a portion of an essential oil is often added. The oil varnishes dry more slowly, and are liable to remain a considerable time clammy. The essential oil employed is usually that of turpentine: the expressed oil that of lintseed, rendered drying by having been expressed by heat; and these are often mixed together. Copal forms the basis of the finer varnishes, but there is considerable difficulty in dissolving it; the addition of camphor renders it more soluble, either in oils or in alcohol.



The name of GUM-RESIN has been applied to a number of substances which have long been employed in the practice of medicine, and which, from the action of solvents on them, appear to be compounds of gum and resin, in different proportions, with portions of extract, and sometimes of wax and vegetable gluten. The principal gum-resins are, aloes, assafoetida, ammoniac, myrrh, gamboge, scammony, and others. They are solid and usually brittle, have often a strong taste and smell, and exert considerable activity on the animal system. Their chemical properties appear to be those of their immediate principles, gum and resin, slightly modified; they are partially soluble either in water or alcohol; the gum and extractive matter being dissolved by the former, and the resin by the latter. Their proper solvent is therefore diluted alcohol, or proof spirit. Alkaline solutions dissolve them; acids decompose them; and in these decompositions they are not so easily converted into artificial tannin as the pure resins. They are decomposed by heat, and with the usual products of the decomposition of vegetable matter, afford a portion of ammonia.

The gum-resin named GUAIAIC appears to have some peculiar properties. It displays, in particular, striking changes of colour from the action of oxygen, chlorine, and of the acids; its solution in alcohol yielding, when decomposed by chlorine, a precipitate of a beautiful pale blue colour; when decomposed by sulphuric acid, one of a pale green colour; and from the action of diluted nitric acid a liquid is obtained, which is at first green, afterwards blue and brown, and affords precipitates of the same colour, on the addition of water. In the direct action, too, of the acids on guaiac, changes of colour are produced,—sulphuric acid forming a solution of a deep-red colour, and nitric acid producing a deep-green tint;



nitric acid also produces oxalic acid with it, a character in which it differs from other resins.

BALSAMS are vegetable products, consisting of resins combined with the acid called Benzoic acid. Their chemical properties are, of course, derived from these principles. They are insoluble in water, but abundantly soluble in alcohol, their solutions being decomposed by the addition of water,—from the precipitation of their resinous matter. The acid is extracted from them, either by applying a gentle heat, when it is volatilized; or by maceration in water, when it is dissolved; or, lastly, by boiling them with an alkali or earth with which the acid unites, and from which it may be afterwards separated by the addition of another acid. The principal balsams are those of Tolu and Peru, as they are named, Storax and Benzoin, the latter being concrete, the former fluid, but thick, and even becoming solid from age; they are odorous and pungent, and are regarded principally as articles of the *Materia Medica*.

SECT. XI.—*Of Extract, or Extractive Matter.*

By expressing the juices of recent herbs, or by boiling the leaves, bark, or wood of vegetables, and evaporating, in either case, the liquor to a thick consistence, preparations are obtained, which, in pharmacy, have been long known by the name of Extracts. It is obvious that these must consist of various proximate principles, which may be soluble in water. But it has been supposed, that a peculiar principle generally forms the basis of them, which has accordingly been termed Extract. It exists, accord-



ing to Sir H. Davy, in large proportion in catechu ; and the extract of saffron is supposed to consist almost entirely of it.

Extract is said to be soluble in water, but to become gradually insoluble from exposure to the air, especially at a high temperature. Thus, if the solution be evaporated, pellicles soon form on the surface, and the solid matter procured by continuing the evaporation cannot be again entirely dissolved in water. In like manner, if its solution be boiled for some time, a large quantity of the extract becomes insoluble, and is precipitated. This change, it has been proved, happens in consequence of absorption of oxygen. The extract thus changed is quite insipid and inert ; and the loss of power which many active medicinal plants sustain by boiling in water, without any volatile principle being dissipated, has been ascribed to an alteration of this kind in the extractive matter, in which their powers are supposed to reside.

Extract is soluble in diluted alcohol, and the solution is not decomposed by water ; acids however precipitate the extract.

Extract has been said to be insoluble in ether ; this in particular is affirmed to be the case with the extract of Saffron ; and from this, and some other properties belonging to it, particularly that of losing its colour from exposure to the air, becoming of a dark blue colour from the action of sulphuric acid, and a green from the action of nitric acid, extract of saffron has been considered as a peculiar principle, and named Polychroite.

Argil exerts an affinity to extract, and forms a flocculent precipitate with it from infusions in which it is dissolved. Several metallic salts, in particular muriate of tin, have a similar effect, in consequence of the attraction exerted by extract to metallic oxides. Extract decomposed by heat affords a portion of ammonia.



In reviewing the characters assigned to this principle, and the facts connected with its chemical history, there is room to doubt if its existence is fully established. There is no process by which we can be certain of having obtained it in an insulated state ; as it exists either in vegetable juices, or as obtained by decoction from any of the parts of plants, it necessarily must be in a state of intermixture, and the properties assigned to it, therefore, may merely arise from modifications produced by such intermixture in other known principles. Some of these properties, too, such as that of absorbing oxygen when in a humid state, or of exerting an affinity to argil or metallic oxides, belong to other principles. And even those qualities which are considered most characteristic of it are not uniform, but are possessed by some varieties of extractive matter, and not by others.

**ULMIN.** A matter is obtained from the Common Elm, (*Ulmus Campestris*,) and, according to Berzelius, may be procured from the bark of most trees, which has been regarded as a variety of extract, but which having peculiar properties, is regarded as a peculiar principle, and has been named Ulmin. It exudes from the bark of the elm ; it is in masses of a black colour, with shining and resinous lustre, insipid, insoluble in alcohol and ether ; and when freed from a portion of potash which adheres to it, sparingly soluble in water. When thus purified, also, it is not precipitated from its solution by acids, burns with flame, and yields white ashes.

A singular circumstance, remarked by Dobereiner, is, that gallic acid may be converted into ulmin, by dissolving the acid in ammonia, and exposing the solution to oxygen gas ; the gas is absorbed, converts part of the hydrogen of the acid into water, and ulmin is produced.



SECT. XII.—*Of Tannin.*

THE property of astringency in vegetables is indicated by a peculiar styptic taste, and by the power of corrugating the animal fibre, displayed in the operation of tanning. With this is connected a peculiar chemical property, that of producing a dark purple colour with the salts of iron, the power of producing this belonging to all vegetable astringents, nearly in proportion to their astringency. An acid having been discovered in the more powerful vegetable astringents, particularly in galls, hence named Gallic acid, which likewise occasions this dark colour with salts of iron, this was supposed to be the astringent principle, —an opinion now proved to be incorrect, as this acid has little astringency, and some powerful astringents contain none of it. Another principle has been accordingly discovered, which is to be regarded as the true principle of astringency. Being the chief agent in the operation of tanning, it has received the name of Tannin. The experiment by which Seguin established its existence, is that of adding to the infusion of a vegetable astringent, as of galls or oak-bark, a solution of animal gelatin, as of glue or isinglass. A copious precipitate is immediately formed, which consists of the gelatin in combination with tannin; the gallic acid, mucilage, or any other principle contained in the astringent, remaining dissolved in the liquor. Other astringents, as various barks, the different kinds of tea, &c. equally afford it, and some, as kino, catechu, and cinchona bark, without any intermixture of gallic acid.

By this process tannin is not obtained in an insulated state; and though various methods have been employed, it is not certain if any of them afford it perfectly pure. One, proposed by Proust, consists in pouring a solution



of muriate of tin into a strong infusion of galls; a precipitate forms from the combination of the tannin with oxide of tin: this is diffused in water, and a current of sulphuretted hydrogen is passed through, which throws down the oxide of tin, and the tannin remains in solution: by gentle evaporation the latter is obtained. Another is, to pour a solution of carbonate of potash into infusion of galls. The tannin is separated in the state of a coagulum, and may be procured by washing with water. As obtained by any of these processes, however, the tannin is mixed with extract and gallic acid, and is probably also partially altered by the operations to which it is subjected. It is said to be procured in a state of greater purity, by evaporating the infusion of galls, digesting the dry mass in successive portions of strong alcohol, to remove the gallic acid, repeatedly dissolving it in water, and evaporating, to oxygenate and separate the extract, abstracting a portion of lime which is mixed with it, by carbonate of potash, adding acetate of lead to its solution, which precipitates the tannin in union with the oxide of lead, and removing the latter by means of sulphuretted hydrogen.

Tannin, by evaporation of its solution, may be obtained in the solid form. It is friable, has a resinous-like fracture, is brown, or of a white colour, which becomes brown from the action of the air; its smell is peculiar, and its taste rough and bitter. It dissolves readily in water, also in alcohol of the usual strength, but not in alcohol highly rectified. In its humid state it is very susceptible of oxygenation. When its solution is exposed to the air, pellicles form on its surface from this cause, and a similar change is produced by exposure to oxygen, or to chlorine gas. By oxygenation it acquires the power of reddening infusion of litmus. It is not liable, however,



to spontaneous decomposition, and is even a powerful antiseptic.

Tannin is precipitated from its solutions by the acids, combinations of the acids, and the tannin being established in different proportions, one forming an insoluble compound, and another one which is dissolved. Nitric acid, after precipitating the tannin, if concentrated, re-acts on it, and decomposes it. The alkalis combine with tannin; a solution of potash or soda first precipitates, but soon re-dissolves it, and suspends its powers of combining with gelatin. Ammonia forms a less soluble compound. The alkaline carbonates have nearly similar effects. Lime, barytes, strontites, and magnesia, form with it compounds of sparing solubility. A number of neutral salts also precipitate tannin from infusions containing it.

Tannin exerts strong attractions to metallic oxides. Precipitates are thrown down from the greater number of metallic salts by the infusion of galls, as well as other astringents, which appear in general to consist of the oxide the base of the salt, united with tannin. These combinations are even established by boiling the infusion on the pure oxide; and by oxide of tin or zinc the whole tannin is thus abstracted: they have been called by some by the incorrect term of *tannates*. The most important combination of this class is that with oxide of iron. It is in consequence of its formation that the infusions of vegetable astringents strike so deep a colour with sulphate and other salts of iron; for although the gallic acid is often associated with tannin, and gives a similar colour, it does so much more faintly, and the intensity of the colour depends chiefly on the tannin. The iron requires to be in a certain state of oxidation for its production, the colour being faint when it is at the *minimum*, while, if more high-



ly oxidated, it is deep. This combination, the tanno-gallate of iron, as it has been called, is the basis of writing-ink, and of the black dyes. The essential ingredients of the former are infusion of galls and sulphate of iron; by their mutual action, the compound of tannin and oxide of iron is formed, which the gallic acid of the infusion, and the sulphuric acid of the salt, contribute to hold suspended or partially dissolved; a portion of gum is added, to give sufficient consistence to the liquid, and frequently a little sugar, to give the ink lustre. The following have been given by Dr Bancroft as the best proportions to form ink,—twelve ounces of galls pounded, and six ounces of logwood, boiled in successive portions of water, so as to afford a gallon of decoction; in which are to be dissolved five ounces of sulphate of iron, five ounces of gum-arabic, and two ounces of unrefined sugar. The decay of ink from age is probably owing to the decomposition of the tannin and of the gallic acid from the slow action of the metallic oxide and sulphuric acid on them. When ink has lost its colour in this manner, it may be restored by washing the faded characters with infusion of galls, the tannin and gallic acid of which unite with the oxide of iron remaining, and form the black compound. Ink is decomposed by alkalis, which separate the oxide of iron, and render the colour brown; the same change is, of course, produced when ink stains are washed with soap. Acids also decompose ink, and destroy the colour by combining with the oxide; hence ink stains may be removed by dilute muriatic acid, or by some of the vegetable acids, as the oxalic. As writing-ink is thus liable, from various causes, to lose its colour, it has been attempted to form inks which will not suffer such changes. Charcoal forms the best basis of an indelible ink, and the easiest form to



obtain this is simply the diffusion of fine lamp black in oil of turpentine, or, as it has been recommended, to dissolve copal in oil of lavender, and then mix the lamp black with the solution.

The most important chemical property of tannin, is that displayed in its relation to animal gelatin. They combine with much facility, forming from a state of solution a soft flocculent precipitate, which on drying becomes hard and brittle: this has been called tanno-gelatine. The combination, it has been shown by Dr Duncan junior, is not always established in the same proportions, but varies according to the concentration of the solutions, and the relative quantities of the substances; nor is the compound in all cases insoluble in water. When the gelatine is only slightly in excess, it consists of 54 gelatin and 46 tannin; when there is a large excess of gelatin, the compound is re-dissolved.

On the formation of this combination depends the art of tanning. The skin of an animal, when freed from the hair, epidermis, and cellular fibre, (which is done in the manipulations of the art, principally by the action of lime,) consists principally of indurated gelatin. By immersion in the tan-liquor, which is an infusion of oak-bark, or other powerful astringents, the combination of the tannin with the organized gelatin, which forms the animal fibre, is slowly established, and the compound of tannin and gelatin not being soluble in water, and not liable to putrefaction, the skin is rendered dense and impermeable, and not subject to the spontaneous change which it would otherwise soon undergo. To render it equal throughout the whole substance of the skin, the action of the tan-liquor must be gradual, and hence the tanning is performed by successive immersion of the skin in liquors of different strength. A portion of the extractive matter of the infu-



sion appears also to enter into the combination. The skin increases in weight from one-fifth to one-third.

Tannin decomposed by heat affords an acid liquor, a brownish oil, and a considerable quantity of carbonic acid, a light spongy charcoal forming the residuum. The determination of its composition is difficult. According to Berzelius, it is composed of 50.55 of carbon, 45 of oxygen, and 4.45 of hydrogen; whence it is inferred to consist of six atoms of carbon, 36, four of oxygen, 32, and three of hydrogen, 3, =71, an equivalent which does not however agree with the analysis of the compound of tannin and oxide of lead. This statement also presents the anomalous result, that tannin, which exhibits no acid properties, differs from gallic acid only in containing an atom *more* of oxygen.

An important fact in the chemical history of this principle, is its artificial formation, discovered by Mr Hatchet. That able chemist shewed, that it is produced in the action of sulphuric and nitric acids on carbonaceous compounds, as on resins, gum-resins, bituminous substances, and many other vegetable and even animal substances. Indeed, he found that it may be procured by the action of nitric acid on charcoal alone, simply by digesting the acid on the charcoal with a gentle heat for several days, and then evaporating the solution, when a reddish-brown substance is obtained, which is the artificial tannin. Some vegetable substances afford this product with great facility, such as peat, for example, which is carbonized vegetable matter; and the tanning quality of peat-mosses is probably owing to a spontaneous formation of tannin.

This product has the general qualities of tannin; its taste is astringent, it combines with gelatin and with oxide of iron, and its relations to other chemical agents are similar to those of this principle. Mr Hatchet observed,



however, that it differs somewhat in its properties as produced in different processes, and he has marked three varieties of artificial tannin;—the *first*, formed by the action of nitric acid on charcoal, approaching nearest to natural tannin, and differing from it only in not being decomposed by the continued action of that acid; the *second*, formed by the repeated distillation of nitric acid from vegetable resins, gum-resins, and balsams, and differing from the other in the colour of the precipitates it forms with gelatin; the *third*, produced by the action of sulphuric acid on the same substances, less energetic in its action on gelatin and skin, and therefore most remote from natural tannin. These differences probably depend on slight variations in the composition which constitutes this principle. They are none of them sufficient to constitute a distinction between the artificial and the natural tannin; indeed, the former may be regarded as the purer form of the principle, being free from extract and gallic acid.

The analysis of the principal astringents was undertaken by Sir H. Davy, with the view of determining the proportion of tannin they contain. Galls contain it in large quantity. Oak bark affords a less proportion, from the predominance of the ligneous fibre: the internal cortical layers of oak bark, however, yield it in considerable quantity. Catechu yields about half its weight of it, and kino appears to contain even a larger proportion.

#### SECT. XIII.—*Of Wood, Cork and Suberic Acid.*

THE wood of vegetables is the base to which the other principles are attached, forming the structure of the plant, and the greater part of the substance of which it is form-



ed. Its properties are sufficiently characteristic to give it a claim to be regarded as a distinct principle.

Wood, Lignin as it has been named, is fibrous in its texture. When purified from admixture of other principles by digestion in water and in alcohol it is inodorous, insipid, and insoluble in water and in alcohol. From the action of the air, if it is dry, it does not suffer any change; but when humid, it is gradually decomposed, and passes through many intermediate states to that of a black mould, consisting principally of carbon. The oxygen of the atmospheric air is, during this change, consumed, and carbonic acid formed, with a portion of water, and the latter, being derived from the combination of the oxygen, leaves carbon predominant. When the air is entirely excluded, wood decomposes with extreme slowness, even though humid, as, for example, when it is buried in the earth.

The alkalis act on wood, and stain it of a dark colour; with the assistance of heat, they soften it, and change it into a substance similar to ulmin.

The stronger acids act on it. Sulphuric acid, according to the experiments of M. Braconnot, changes it into gum, and this by being boiled for 10 or 12 hours in water, is converted into a species of sugar. Other vegetable substances, composed chiefly of woody fibre, as linen, hemp, bark, and straw, were also found by Braconnot to yield sugar by the same process. Nitric acid gives to lignin a yellow tinge, and finally converts it into oxalic acid, with small quantities of malic and acetic acids.

When wood is heated in close vessels, as in iron cylinders, the method commonly used, it is decomposed, a quantity of impure acetic acid, Pyro-ligneous Acid, as it has been called, is obtained, and a large bulk of charcoal, retaining the figure and even the texture of the wood, re-



mains. The pyro-ligneous acid is much used in the preservation of animal food, as it has valuable antiseptic qualities. By purifying it, very strong vinegar is procured. The charcoal obtained in this process is much purer than that prepared in the common way; hence it is now commonly employed in the manufacture of gunpowder. In the destructive distillation of wood a spirituous fluid is formed, first noticed by Mr P. Taylor, and since examined by MM. Macaire and Marcet. It is colourless and transparent, with a strong pungent ethereal odour, and a flavour like that of oil of peppermint. Its specific gravity is 0.828; it boils at  $150^{\circ}$ ; it burns with a blue flame, and is wholly consumed; it is soluble in alcohol, and to a certain degree in water; it is so far analogous to alcohol as to yield an ether with nitric acid and chlorine, but does not afford an ether with sulphuric acid. It has been called by MM. Macaire and Marcet, Pyroxilic Spirit. They infer it to consist of 6 atoms of carbon, 4 of oxygen, and 7 of hydrogen. The Pyro-acetic spirit, obtained by Chenevix by distilling some metallic acetates, resembles it in some particulars, but burns with a yellow flame, and unites with oil of turpentine: it consists of 4 atoms of carbon, 2 of oxygen, and 3 of hydrogen.

When the air is admitted, and the heat raised to ignition, wood burns. Its combustion at first gives much light, from the formation and extrication of carburetted hydrogen; this soon ceases, and the charcoal remains, which burns with its usual red light. The products of the combustion are principally carbonic acid and water; nitrogen appears to be a constituent principle of wood; ammonia therefore is also evolved, and accordingly an ammoniacal salt is found in the soot of fuel: it consists, according to Gay-Lussac, of carbon 52.5, oxygen 41.8, and hydrogen 5.7.



CORK, the external bark of the *Quercus Suber*, is analogous to wood. It is light, soft, spongy, and elastic; it is inflammable; it affords a little ammonia by distillation: according to Chevreul it consists of several principles, one which he calls *Cerin*, analogous to wax; the other, of which it is principally composed, he calls, when pure, *Suberin*. The chief peculiarity of cork is that of yielding a peculiar acid, hence named the Suberic.

To obtain this acid, diluted nitric acid is distilled from cork with a gentle heat, the distillation being continued until the production of red vapours ceases; the whole, while warm, is poured into a porcelain bason, placed on a sand-bath, and a moderate heat is applied, stirring the matter constantly until it ceases to exhale white irritating vapours. A concrete soft substance is thus obtained, of a yellow colour, which is to be heated in a matrass, with twice its weight of distilled water. The filtered solution by evaporation gives suberic acid.

Suberic acid is not crystallizable; its taste is slightly acid; it reddens the vegetable colours. Exposed to heat, it is sublimed, and forms crystalline flakes on the sides of the vessel. It is soluble in 80 parts of cold water, and in two parts of boiling water, also in alcohol. It unites with the alkalis and earths, forming salts, named Suberates. A character regarded as peculiar to this acid is, that when a few drops of it are added to a solution of indigo in sulphuric acid, it causes the blue colour to pass to a green. This acid has a very great analogy with the Sebacic acid; the principal difference between them being the crystalline form which the suberic acid assumes by evaporation from its solutions.



SECT. XIV.—*Of Vegetable Acids.*

THERE exist in the juices of many plants, at certain periods of their vegetation, peculiar acids, and the same or other acids are likewise found combined with some of the vegetable proximate principles, or united with alkaline or earthy bases, forming what have been named the Essential Salts of Plants. Of these native vegetable acids, the principal are the Gallic, Malic, Citric, Oxalic, Tartaric, Benzoic, Acetic, and Moroxylic, and the Prussic, though the latter is more usually ranked among the substances belonging to the animal kingdom: there are some others of minor importance, which will be noticed after these. These acids have a compound base of carbon and hydrogen, and differ principally in the proportions of their elements; hence they are convertible into each other. The oxalic is the one into which the greatest number of the others are changed.

## GALLIC ACID.

GALLIC acid may be considered the first of these, as having an intimate connection with the principle already described, tannin: they are generally associated in the vegetable astringents, and they are similar in some of their most striking chemical relations. It derives its name from the gall-nut, in which it exists in large quantity, and from which it is usually obtained. Its presence is shown by the property which the infusion of galls has of reddening litmus; and it may be procured by a process given by Scheele,—merely allowing a strong infusion to remain in a vessel imperfectly closed for some months; a sediment



is deposited; this being washed with cold water, and dissolved in boiling water, crystals of a yellowish colour are procured, which are the acid. These may be purified by being digested with animal charcoal. Scheele showed also that gallic acid may be obtained by sublimation, when it is in a concrete crystalline form. Other methods have been employed, such as dissolving the acid by highly concentrated alcohol, which leaves the tannin undissolved,—abstracting the tannin and extract of the infusion of galls by the affinity of argil;—or boiling in the infusion carbonate of barytes, and decomposing the gallate of barytes by sulphuric acid. But by none of these processes, by chemical affinity, is the acid obtained in a state of purity, and in particular it is never free from tannin. By the process of sublimation the gallic acid may be rendered more pure, a minute portion of oily matter only adhering to it, which gives it a slight aromatic odour: it gives no precipitate with gelatin, and therefore does not appear to have any intermixture of tannin: it would appear, however, that its properties are in some degree altered by this process. With regard to the different states of this acid, and its purity, there still remains, on the whole, considerable uncertainty, and its peculiar relation to tannin is still unexplained.

Gallic acid, procured by sublimation, or by crystallization from its solution, is in slender prisms, which have a sour taste; it reddens, though not very deeply, the vegetable colours, and excites effervescence in the alkaline carbonates; it requires 24 parts of cold water for its solution, but dissolves in less than two parts of boiling water, this solution crystallizing on cooling. It dissolves in 4 parts of cold alcohol. Exposed to heat it fuses, exhaling an agreeable odour; a portion sublimes, and condenses in crystals, while a quantity of acid liquor is also



produced, and a large quantity of charcoal remains in the retort. The products of its entire decomposition prove it to be a compound of carbon, hydrogen, and oxygen, containing a large proportion of carbon. By nitric acid it is converted into oxalic acid. According to Berzelius it consists of carbon 56.64, oxygen 38.36, and hydrogen 5: it is hence inferred to be composed of six atoms of carbon, 36, three of oxygen, 24, and three of hydrogen, 3, = 63.

Gallic acid combines with the alkalis and earths. Its salts are named Gallates; they have been little examined: those with the alkalis are soluble; they throw down dark-coloured precipitates from metallic solutions similar to those produced by the acid itself. This property of forming dark-coloured precipitates with the solutions of metals is the most important one belonging to the gallic acid, as rendering it a re-agent of considerable delicacy; at least when it is in combination with, or mixed with tannin; for, as it has not been procured with certainty free from that principle, it cannot be affirmed what its action would be in a perfectly pure form. With the salts of iron it has been already mentioned it strikes a violet or purple colour, more or less deep; but for the production of the colour, the iron requires to be in a high state of oxidation. The colour, from the action of gallic acid, is less deep than that from tannin; and the precipitate is much finer, and remains longer suspended. There is some reason to suspect, that the colour is always produced by tannin adhering to the acid, and that the acid, only by its re-action on the precipitate, holds it dissolved.

From this relation subsisting between gallic acid and tannin on oxide of iron, arises the advantage derived from their combination in the formation of writing-ink or black dyes, or the superiority of the infusion of a vege-



table astringent, in producing the colour, to either of them in its separate state.

#### MALIC ACID.

THE juices of unripe fruit are in general sour, and this is owing principally to the presence of an acid, which being abundant in the fruit of the apple, has been named Malic Acid. It exists in many other unripe fruits, particularly in the plumb, sloe, barberry, gooseberry, and currant, mixed more or less with another acid, the citric. To obtain it pure, acetate of lead is added, either to the juice containing it, or to this juice previously neutralized by carbonate of potash; malate of lead is formed in white crystals of much beauty; this is then decomposed by diluted sulphuric acid. This acid is also artificially formed in the action of nitric acid on secula, sugar, and other vegetable principles, and is separated from the oxalic acid, generally formed in the same processes by the addition of lime-water, which forms with the oxalic acid an insoluble compound, with the malic acid one that remains dissolved.

Malic acid, however far its solution may be evaporated, does not crystallize, a property by which it is distinguished from the other vegetable acids. It acquires a brown colour, and becomes thick: its taste is extremely sour, and it reddens strongly the vegetable colours. It suffers spontaneous decomposition. It is charred by sulphuric acid. By nitric acid, it is converted into oxalic acid. When heated out of contact of the air it sublimes; and as its properties are different after this sublimation, it has been supposed to become a new acid, and has been termed the Pyro-malic. From its analysis by Vauquelin, malic acid would appear to consist of carbon 28.3, oxygen



54.9, and hydrogen 16.8; or to be composed of three atoms of carbon, 18, four of oxygen, 32, and ten of hydrogen, 10, = 60, an excess of hydrogen which renders the analysis improbable.

This acid combines with the alkalis and earths, forming salts denominated Malates. Almost all of them are soluble and deliquescent: the malate of lime, however, is scarcely soluble in cold water, but is readily soluble in hot water: the malate of lead is also soluble in hot, but not in cold water. These circumstances are characteristic of this acid.

An acid was obtained by Mr Donovan from the berries of the *Sorbus aucuparia*, which he considered to be different from malic acid, and hence named it Sorbic Acid. Braconnot and Houton Labillardiere have shewn, however, that it is merely the malic acid disguised by some impurities.

#### CITRIC ACID.

THIS acid exists in the lime, the lemon, the tamarind, and many other sour fruits. It is usually obtained from them by the process given by Scheele. To the expressed juice of the lemon, after filtration, chalk in fine powder is added as long as any effervescence is produced. Insoluble citrate of lime is formed, which being washed is decomposed by adding half its weight of sulphuric acid, diluted with six parts of water, the action being promoted by a gentle heat. The sulphate of lime is precipitated, the citric acid remains dissolved, and by evaporation may be obtained in a crystalline form. The crystallization is more easily effected when a slight excess of sulphuric acid has been added. If the acid is coloured brown, it may be obtained white by a second crystallization.



Its crystals are rhomboidal prisms; they are permanent in the air, or slightly efflorescent; they are soluble in their own weight of cold water, and in half their weight of boiling water. The solution has an extremely sour taste, and reddens deeply the vegetable colours. The equivalent of citric acid has been fixed by Berzelius and Thomson, from their analyses of the citrate of lead, at 58; and its crystals have been shown to consist of one atom of acid, 58, and two of water, 18, = 76. From the proportions of the elements assigned by Berzelius, it would appear that the dry citric acid is composed of four atoms of carbon, 24, four of oxygen, 32, and two of hydrogen, 2, = 58; a number which thus agrees with that deduced from the citrate of lead.

Citric acid combines with the alkalis, earths, and metallic oxides; citrate of potash is soluble, deliquescent, and does not easily crystallize; citrate of soda is likewise very soluble, but crystallizes readily in six-sided prisms, which are efflorescent; citrate of ammonia also crystallizes, though with difficulty, in elongated prisms. The earthy citrates are much less soluble: all the alkaline citrates are precipitated both by barytes and lime, and the precipitate with lime requires 500 parts of water to dissolve it. The metallic citrates are unimportant. The equivalents of these salts will be found in the table in the Appendix, but they are none of them established with perfect certainty.

Citric acid is preserved in its crystallized state for any length of time without decomposition, and is used dissolved in water to form a grateful refrigerant beverage.

When crystals of citric acid are heated, they undergo the watery fusion, and before the whole of the water is dissipated are decomposed, yielding an acid and an oily fluid, from which, by saturation with lime or acetate of



lead, a peculiar acid is obtained. This, from its origin, has been called Pyro-Citric acid. It is said to form salts, differing considerably from the citrates of the same bases. It agrees in saturating power with the citric acid, whence its equivalent might be supposed to be the same; but from its analysis, it is inferred to consist of eight atoms of carbon, 48, five of oxygen, 40, and nine of hydrogen, 9, = 97.

#### OXALIC ACID.

THIS acid exists in the juice of the leaves of the sorrel, (*Oxalis acetosella*), combined with a portion of potash not sufficient to neutralize it. This salt, the super-oxalate or bin-oxalate of potash, is obtained by expressing the juice, allowing the impurities to subside, and clarifying it by boiling it with water, in which a small portion of fine clay is suspended. After due evaporation, the salt crystallizes, and is purified by a second crystallization. From the binoxalate of potash the oxalic acid may be procured, by adding to its solution acetate of lead, as long as there is any precipitation; the oxalate of lead, being washed, is decomposed by sulphuric acid, which combining with the oxide of lead, the oxalic acid is disengaged. This acid can also be formed by an artificial process; and as this is easily conducted, it is more frequently obtained by it than from the native salt. One part of refined sugar in powder is put into a retort with three parts of nitrous acid; a strong mutual action is exerted, and nitrous acid vapours are disengaged; when this has ceased, an additional portion of acid is added, and a moderate heat applied; the liquor, on cooling, affords a large quantity of oxalic acid, crystallized in slender prisms. The uncrystallizable liquid, which contains malic acid, being removed, the cry-



stals are purified by solution, and a second crystallization. The nitric acid in this process appears to act by communicating oxygen, which combines with a portion of the carbon, and with all the hydrogen of the sugar, forming water and carbonic acid: and thus the oxalic acid, which contains no hydrogen, and but a small proportion of carbon, is produced. It is obtained, by a similar process, from fecula, gum, and many other vegetable products.

Oxalic acid crystallizes in slender four-sided rhomboidal prisms; the crystals, when pure, are white and transparent. Their taste is intensely sour, and they redden deeply the vegetable colours. They are soluble in alcohol, in twice their weight of cold water, and in an equal weight of boiling water. They are calculated to contain exactly half their weight of water, being composed of one atom of acid, 36, and four atoms of water, 36, = 72. Of this water little more than half can be expelled by heat, without decomposing the acid.

From the analysis of this acid by Gay-Lussac and Thenard, it had been supposed to contain about 2.7 *per cent.* of hydrogen, with carbon and oxygen. This quantity, however, is so small, that it may readily be attributed to adhering moisture, as it besides conforms to no atomic proportion. Döbereiner accordingly inferred, in 1815, that the real acid, such as it exists in its compounds, contains no hydrogen, but is a compound of carbon and oxygen alone, in proportions intermediate between those of carbonic oxide and carbonic acid; and this opinion has been confirmed by the researches of Berzelius and Thomson. On this view, oxalic acid consists of two atoms of carbon, 12, and three of oxygen, 24, whence its equivalent is 36; or it may be regarded as composed of one equivalent of carbonic acid, 22, and one of carbonic oxide, 14, = 36. It thus contains a larger proportion of oxy-



gen than any other vegetable, or animal substance\*. Dobereiner has shown that, by the action of a large excess of fuming sulphuric acid, oxalic acid is converted into carbonic acid and carbonic oxide gases, a result supposed to confirm his view of its nature.

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\* On Dr Murray's views relative to acidity, already explained, (vol. i. p. 499,) oxalic acid is rather to be regarded as a ternary compound of carbon, oxygen, and hydrogen, as it can never be obtained free from combined water; and the existence of what is called the dry acid, is thus altogether hypothetical. Supposing it to be a ternary compound, it may either contain one or two atoms of water in its constitution, as it does not appear that more than two atoms of water can be expelled from its crystals, which are known to contain four. On the former supposition, oxalic acid will consist of two atoms of carbon, 12, with four of oxygen, 32, and one of hydrogen, 1, = 45; or the carbon will be acidified by two proportions of oxygen, as it is in carbonic acid, and will, at the same time, have its acidity exalted by the hydrogen, which it has been shown is an element conferring, like oxygen, both acid and alkaline powers: Or supposing the old view of the nature of muriatic and oxymuriatic acids to be correct, oxalic acid will stand in the same relation to the carbonic, that the muriatic does to the oxymuriatic acid, an analogy which likewise accounts for its being an acid of considerable power. If it be supposed to contain two atoms of water, it will consist of two of carbon, 12, five of oxygen, 40, and two of hydrogen, 2, = 54. Either of these views assigns a more energetic composition to oxalic acid, than the common notion, of conceiving it to be intermediate between carbonic oxide and carbonic acid; for if the latter opinion were true, it certainly ought to be an acid weaker than the carbonic, whereas it is much stronger. The experiment of Dobereiner, too, is rather adverse to his own doctrine; for the action of the sulphuric acid can only be to abstract the water of composition; and when this is removed, it appears that the three atoms of oxygen and two of carbon are not disposed to form a simultaneous combination, but rather to separate in the state of binary compounds. ED.



This acid exerts affinities of considerable strength to the alkalis and earths. Its salts are named Oxalates. Many of these salts are of very sparing solubility; and with those bases, with which it forms soluble salts, it has a tendency to establish combinations with an excess of acid, forming binoxalates, and in some cases quadroxalates, which are, in general, even less soluble than the neutral compounds.

The oxalates are all soluble in nitric acid and in muriatic acid, unless the bases form with the latter insoluble chlorides. Neutral oxalate of potash is very soluble, requiring only 3 parts of water at  $60^{\circ}$  for solution; its crystals are rhomboidal prisms: it consists of one atom of oxalic acid, 36, one of potash, 48, and one of water, 9, = 93. The binoxalate, which contains double the quantity of acid, is less soluble, and crystallizes in four-sided prisms; it is composed of two atoms of acid, 72, one of potash, 48, and two of water, 18, = 138. A quadroxalate of potash also may be obtained, by digesting the binoxalate in nitric or muriatic acid, which abstracts half of the potash, and a salt crystallizes, containing, therefore, twice as much acid as the binoxalate: its crystals consist of four atoms of acid, 144, one of potash, 48, and seven of water, 63, = 255; it is less soluble than either of the former. Oxalate of soda, when neutral, is not very soluble; the binoxalate is still less soluble, and difficult to crystallize. Oxalate of ammonia, much used as a reagent for detecting lime, is obtained by saturating the acid with ammonia, in crystals, which contain two atoms of water. The earthy oxalates, with the exception of oxalate of alumina, are of very sparing solubility: that of strontites is nearly insoluble; that of barytes is more soluble, which is an exception to the usual law with regard to the solubility of these two earths: from this greater



solubility, too, the oxalate of barytes can combine with an excess of acid, forming a super-oxalate. Oxalate of lime is extremely insoluble; and as this acid attracts lime from any other acid, while lime on the other hand attracts the oxalic acid from any other base, they serve as the most delicate tests to discover each other. When thoroughly dried by a temperature of 4 or 500°, it consists of one atom of oxalic acid, 36, and one of lime, 28, = 64; at a red heat, it is converted into a carbonate: it is easily decomposed by alkaline carbonates, but not by pure alkalis. Oxalate of magnesia is insoluble. The metallic oxalates are in general insoluble; several of them, as the oxalate of cobalt, when heated, are not only decomposed, but the base is reduced, the oxygen of the oxide uniting with the oxalic acid, and forming carbonic acid, which escapes, leaving the pure metal.

Oxalic acid is principally employed as a test of lime. It proves highly poisonous, and fatal accidents have occurred from its being taken by mistake for Epsom salts, to which it bears considerable resemblance. Such mistakes may be guarded against by previously tasting a small quantity of the crystals, when the intensely sour taste of the acid will be easily distinguished from the bitter taste of the salt; or by placing a little of it moistened on blue paper, which the acid will render red. The best antidote to oxalic acid is powdered chalk or magnesia. The bin-oxalate of potash, under the name of Salt of Lemon, is used to remove ink stains, an effect which it produces by dissolving the oxide of iron, which, with tannin, forms the colouring matter of ink.



## TARTARIC ACID.

THIS acid, as it exists in vegetables, is usually combined with potash, forming a salt with an excess of acid,—the super-tartrate or bi-tartrate of potash. This salt is deposited in considerable quantity from the juice of the grape during its conversion into wine, or rather from the wine during the slow fermentation it suffers in the cask. It does not appear to be a product of the fermentative process, but pre-exists in the juice of the grape, and is merely separated. It also exists in other fruits, particularly in the tamarind, of which it forms a considerable part. As deposited from wine it is impure, having associated with it colouring matter and tartrate of lime. In this state it forms the Crude Tartar of commerce, named White or Red Tartar, according to its colour. It is purified by boiling it in water, with the addition of a small quantity of fine clay, which attracts the colouring matter. By evaporation it is obtained crystallized, forming the purified Tartar, Crystals or Cream of Tartar of the shops.

From this salt the tartaric acid is obtained by adding to a solution of the super-tartrate of potash in boiling water, carbonate of lime in powder, as long as any effervescence is excited; the tartrate of lime which is formed and precipitated, being well washed, is decomposed by adding sulphuric acid equal in weight to the chalk that had been employed, previously diluted with half its weight of water, digesting them with a moderate heat; the sulphuric acid combines with the lime, and forms the sulphate, which, being of sparing solubility, is separated, while the tartaric acid is dissolved by the water, and by evaporation is obtained in a crystallized form.



The crystals of this acid are tables or prisms, white and nearly transparent; their taste is very sour, and they redden deeply the vegetable colours. They are very soluble in water, and form a solution so concentrated as to have an oily appearance. By the action of very strong nitric acid, they are converted into oxalic acid.

From the analysis of Berzelius, tartaric acid is inferred to consist of four atoms of carbon, 24, five of oxygen, 40, and two of hydrogen, 2, =66, an equivalent which agrees with that deduced from examination of its salts; its crystals are composed of one atom of acid, 66, and one of water, 9, =75.

Tartaric acid is decomposed by heat, affording, among other products, a white sublimate, which is a peculiar acid, named, from its origin, Pyro-tartaric acid; it has been supposed to be acetic acid, disguised by the addition of a little oily matter. But it differs from the acetic in being capable of crystallizing, and in being less volatile, while it differs from the tartaric in the compounds it forms; it has no tendency, in particular, to form with potash an acidulous salt of sparing solubility, and it does not precipitate the salts of barytes or lime.

Tartaric acid combines with the alkalis and earths, forming salts, named Tartrates. The acid appears to have a peculiar tendency to enter into combination with more than one base, and to form ternary salts, which crystallize with much regularity, and are of uniform composition. It has also a tendency to form salts with an excess of acid, in uniting with those bases with which it forms soluble compounds.

Tartrate of potash is usually formed by neutralizing the excess of acid in the bi-tartrate, by the addition of carbonate of potash. From its affinity to water, it is not easily obtained crystallized; by slow evaporation, how-



ever, in a dry atmosphere, crystals in the form of four-sided prisms are procured. It is deliquescent in a humid atmosphere, and very soluble in water, whence its name of Soluble Tartar. It is very susceptible of decomposition, so far as relates to the abstraction of that portion of alkali which renders it neutral, and hence it is converted by the action even of weak acids into the bi-tartrate. The bi-tartrate of potash, or cream of tartar, is sparingly soluble in water, requiring 60 parts of cold and 30 of boiling water for its solution. Hence, when tartaric acid is added to solutions of any of the salts of potash, this bi-tartrate is precipitated, a circumstance characteristic of tartaric acid and of potash. It concretes from the hot solution in small irregular crystalline masses, white and semi-transparent. Its taste is sour, from the predominance of acid in it; this excess of acid enables it to act on many substances, as if it were itself a simple acid; and even a more remarkable property is that from the co-operating affinity of the alkali, this salt dissolves various metallic oxides, which are insoluble not only in tartaric acid, but in the more powerful mineral acids. It consists of two atoms of tartaric acid, 132, one of potash, 48, and one of water, 9, = 189. It is decomposed by heat, the acid being converted into carbonic acid, so that carbonate of potash is obtained.

Tartrate of soda is soluble and crystallizable. A triple salt, the tartrate of potash and soda, formerly named Rochelle Salt, is formed by neutralizing the excess of acid in the super-tartrate of potash, by adding carbonate of soda. It crystallizes in rhomboidal prisms, soluble in 5 parts of water; it consists of one atom of tartrate of potash, 114, and one of tartrate of soda, 98, = 212. Tartrate of ammonia is a very soluble salt. The Tartrates of barytes and lime are insoluble; those of magnesia and argil do



not crystallize, their solutions becoming gelatinous on evaporation.

Tartaric acid acts on some of the metals, and it may be combined with the oxides of all of them by double affinity.

By employing the bi-tartrate of potash to act on these oxides ternary compounds are obtained. The most important of them is that formed with oxide of antimony, the preparation and properties of which have been noticed under the history of that metal.

#### BENZOIC ACID.

THIS acid exists in the natural balsams, as benzoin, and those of Peru and Tolu, in combination with resin and essential oil, and is obtained from them by the application of a moderate heat,—from the one named Benzoin in largest quantity, whence its name; it rises in vapour, and condenses in slender prisms. It can also be extracted by boiling the benzoin in water, and evaporating the solution; or in larger quantity, by boiling slaked lime with benzoin, and decomposing the benzoate of lime which is formed, by adding to the liquor when cold muriatic acid; the benzoic acid is precipitated, and by sublimation is obtained pure. In all these cases the benzoic acid appears to be merely extracted from the balsam in which it exists, and not formed, as some chemists have supposed. Vogel has found it in a crystallized state between the skin and kernel of the Tonquin bean. This acid is not only a vegetable product, but belongs also to the animal kingdom, being sometimes found in the urine of graminivorous animals; also in that of children; and in general, indeed, when the phosphoric acid of that secretion is deficient.



Benzoic acid is, according to the usual method in which it is obtained, in soft light flakes, or in slender needle-like crystals; when pure, white and brilliant. Its taste is pungent and slightly acidulous. It has a peculiar aromatic odour, which becomes strong when it is heated and volatilized. This acid is fusible; and when it has become solid after fusion, its surface exhibits a stellular radiated appearance. It is also volatile. Heated on burning fuel, it inflames, burning with a clear yellow flame. From its analysis by Berzelius, it is inferred to consist of fifteen atoms of carbon, 90, three of oxygen, 24, and six of hydrogen, 6, = 120, an equivalent which agrees also with that deduced from the analysis of benzoate of lead.

It is sparingly soluble in cold water, requiring according to Bucholz 200 parts at 60°; 24 parts of boiling water dissolve it. Its solution reddens the infusion of litmus. Alcohol dissolves it abundantly; and it is precipitated from this solution by the addition of cold water. Benzoic acid is not easily decomposed by the mineral acids; they dissolve it, but it is precipitated again by water little changed.

This acid unites with the alkalis and earths, forming salts denominated Benzoates; their properties are not important. They are all soluble, even those with earthy bases, and in general crystallizable. The metallic benzoates are equally uninteresting. The benzoate of iron, it has lately been observed, is insoluble; and this affords a mode of precipitating iron from its solutions, so as to estimate its quantity, and also of obtaining it free from manganese, which forms with this acid a soluble salt. The orange colour of benzoate of iron is also a useful indication of iron, as the other insoluble benzoates are white. The solutions of iron must be at the *maximum* of oxidation, neutral and diluted; benzoate of ammonia is added,



and the precipitate of benzoate of iron is collected and dried by exposure to the air. The acid itself, though retained in the *Materia Medica*, has no medicinal virtue, and is employed merely in some officinal preparations, particularly in preparing the Paregoric Elixir, in which it has long been an ingredient.

#### ACETIC ACID.

THIS, like several of the other vegetable acids, is a native production, and is also capable of being artificially formed. It exists in the sap of vegetables, combined with potash and lime, and is discovered by evaporating the sap, and adding to the solid matter sulphuric acid; the vapours of acetic acid are then perceived by their smell. It is more peculiarly, however, the produce of fermentation. It is under that process, therefore, that its chemical history is placed.

#### PRUSSIC ACID.

PRUSSIC ACID is usually obtained in the decomposition of certain animal substances by heat. But it has been discovered also to exist as a product of the vegetable system, in the distilled waters from the leaves of the cherry-laurel, the seeds of the bitter almond, the peach blossom, and some similar vegetables, in which its presence was first suspected, from its peculiar fragrant odour being distinguished in them. Even prussiate of potash is obtained crystallized, by distilling these from potash, or adding the alkali to the oil of these plants. As this acid is more peculiarly formed from animal matter, and is more analogous in composition to animal substances, its history will be afterwards delivered.



## MOROXYLIC ACID.

THIS name has been given by Klaproth to a peculiar acid which is extracted from small yellowish grains that exude from the trunk of the white mulberry (*Morus alba*.) To obtain it these grains are dissolved in water, and acetate of lead added; moroxylate of lead is precipitated, from which the acid is separated by sulphuric acid. By evaporation, it is procured in acicular crystals, soluble in water and alcohol; they are not changed by exposure to the air; exposed to heat they sublime. This acid is in many characters similar to the succinic; it differs in not precipitating metallic solutions.

These are the principal native vegetable acids. There are some others of less importance. The BOLETIC ACID, obtained from the juice of the *Boletus pseudo-igniarius*, crystallizes in four-sided prisms, sparingly soluble in alcohol, and very sparingly so in water; it forms insoluble compounds with oxides of iron, silver and mercury. The KINIC ACID will be described in connection with Cinchonin, and the MECONIC in connection with Morphin. The IGASURIC ACID, obtained by Pelletier and Caventou from St Ignatius's bean, is so similar in properties to the malic, that its existence as a peculiar acid is doubtful. The ZUMIC ACID, obtained by Braconnot from some vegetable substances which have undergone the acetous fermentation, has been shown by Vogel to be the same with the Lactic acid. The RHEUMIC ACID, supposed to exist in the stems of garden rhubarb, has been found to be merely impure oxalic acid. The ELLAGIC ACID, obtained along with gallic acid from galls, can scarcely be regarded as an acid; it is a tasteless white powder.



SECT. XV.—*Of Vegetable Alkalis.*

THE substances which have been so termed, appear to be the active principles of a number of plants which have long been valued for their medicinal virtues. These principles have, by the researches of various chemists, been obtained in an insulated state, and their peculiar and interesting characters have been examined. As they combine readily with acids, and in some measure neutralize the acid properties, the appellation of alkalis has been given to them, which, however, they scarcely merit, bearing little resemblance in general characters to that important class of bodies. Indeed, as chemical agents, their powers are feeble, and from their liability to decomposition, their actions are limited. It is chiefly in affecting the animal system that they act with energy, many of them, even in very small quantities, acting as rapid and virulent poisons. They appear to exist ready formed in the plants to which they communicate their peculiar properties; but are generally, perhaps always, in combination with one or other of the vegetable acids, forming compounds which may be termed salts; hence, the principal part of the processes for procuring them, consists in obtaining these salts by macerating or digesting the plants in water, and afterwards adding potash, ammonia, or magnesia, which, from their greater alkaline energy, unite with the vegetable acids, and separate the peculiar principles. They are, for the most part, almost insoluble in water, and sparingly soluble in cold alcohol: by boiling alcohol they are readily dissolved, being again deposited, frequently in crystals, from the solutions when cold. Their salts, either with vegetable or mineral acids, are much more soluble, and consequently more active than the principles them-



selves, and hence, such of these principles as are used in medicine, are commonly given in combination with some acid, as the acetate of morphine, and the sulphate of quinine. They differ from most other vegetable products in containing a considerable proportion of nitrogen; hence, in their decomposition by heat, they always yield ammonia. The composition of the principal of these vegetable alkalis is given in the following table, by Pelletier and Dumas.

	Carbon.	Oxygen.	Hydrogen.	Nitrogen.
Morphine, .....	72.02	14.84	7.01	5.53
Emetine, .....	64.57	22.95	7.77	4.3
Cinchonine, .....	76.97	7.79	6.22	9.02
Quinine, .....	75	10.43	6.66	8.45
Brucine, .....	75.04	11.21	6.52	7.22
Veratrine, .....	66.75	19.6	8.54	5.04
Strychnine, .....	78.22	6.38	6.54	8.92
Narcotine, .....	68.88	18.	5.91	7.21
Cafeine, .....	46.51	27.14	4.81	21.54

From the difficulty of examining and estimating the complicated products of their decomposition, there is, however, still considerable uncertainty as to the precise constitution of these bodies; thus, some of them have been affirmed to contain no nitrogen, and others no oxygen: as far the greater number contain the four elements that have been stated, it is probable that the rest, which are similar in properties, are also analogous in composition. From their constitution being so complicated, their equivalents are very large, some of them being even above 300 to hydrogen as 1; their saturating power is, of course, proportionally weak.

The substances of this class have been discovered chief-



ly by the labours of Sertuerner, Robiquet, Pelletier, and Caventou. Those that were first detected were morphine, by Sertuerner, and cinchonine, by Dr Duncan jun., in 1803. Several of them are now extensively used as valuable remedies in medicine, possessing all the virtues of the original plants, and being freed from other noxious principles, with which, in these plants, they are associated.

In conformity with the appellation of alkalis which has been given to these principles, it has been proposed to modify the names, which were first applied to them, of morphine, cinchonine, emetine, &c. to names terminating in *a*, as morphia, cinchonia, emetia, &c. This nomenclature has the disadvantage, however, that the names of many plants from which these principles are procured end likewise in *a*, as cinchona, atropa, &c. and thus the distinction is not sufficiently established between their vegetables and their active principle. The original names ending in *ine*, are, therefore, upon the whole, preferable.

The processes for extracting these principles, and obtaining them pure and uncombined, are, in general, very similar. By macerating the plant, the alkaline principle is obtained in union with some vegetable acid, and by the addition of a mineral alkali it is separated and precipitated. To purify it, it is then mixed with a little animal charcoal, and dissolved in boiling alcohol; the solution is filtered while hot, and when it cools, the principle is usually deposited nearly pure: by repeating this latter operation, it may be obtained pure and colourless. Or a method perhaps more economical, is to combine the alkali when deposited, with some acid, as the acetic or sulphuric, then to boil the dissolved salt with animal charcoal, and afterwards to precipitate the principle by ammonia.



## MORPHINE.

THIS is one of the most important of the vegetable alkalis. It is obtained from Opium, the concrete juice of the *Papaver somniferum*, in which it exists combined with a peculiar vegetable acid,—the meconic; it has been found also in the juices of other narcotic plants, as of the *Lactuca virosa* and *Lactuca sativa*. Opium is the substance in which it was discovered by Sertuerner, and from which it is always procured. Along with Morphine and meconic acid, this vegetable product contains a peculiar principle termed narcotine, resin, mucilage, extractive matter, a matter analogous to caoutchouc, vegetable fibre, and a portion of fixed oil. To separate the alkaline principle from these different substances, requires processes somewhat complicated.

The method which is commonly followed is that recommended by M. Robiquet. 1000 parts of opium are to be macerated for several days in about three or four times as much water, and the filtered solution boiled with 50 parts of pure magnesia for a quarter of an hour. A greyish crystalline precipitate subsides, which consists of meconate of magnesia, morphine, (narcotine,) and extractive colouring matter. This deposit is washed repeatedly with cold water, and then digested in diluted alcohol, (sp. gr. 920,) at a temperature between 100° and 150°, as long as the warm alcohol takes up any colouring matter; in this way the greater portion of the narcotine is removed. The powder is then boiled for a few minutes in strong alcohol, (.850,) which dissolves the morphine, and deposits it again on cooling in crystals. To purify it more completely, this last operation is repeated on it for three or four times, and the morphine is then obtain-



ed pure, crystallized in small rectangular prisms of a brilliant and pearly lustre. By this process, according to Mr Brande, about 500 grains of morphine are, on an average, procured from a pound of good opium, or about  $\frac{1}{4}$ th of its weight.

A process has been recommended by Dr Thomson, more easily performed than this of Robiquet, but which scarcely perhaps affords so large a product. It consists in adding, instead of magnesia, solution of ammonia to a strong infusion of opium; the alkali combines with the meconic acid, and precipitates the greater part of the morphine in the state of a brownish powder; this is separated by filtration, the infusion is then evaporated to a sixth of its volume, and on treating it again with ammonia, a farther precipitation of morphine takes place. These precipitates are washed with cold water, and a little alcohol poured upon them, which is allowed to pass through the filter, carrying along with it a large quantity of colouring matter. The morphine is then dissolved in acetic acid, and to purify it completely, the solution is mixed with ivory black; this animal charcoal in a few hours renders the liquor quite colourless; ammonia is then added, which precipitates the morphine, and by solution in alcohol and slow evaporation, the latter is obtained crystallized.

Morphine, when pure, is white and inodorous; it is very sparingly soluble in water, but is readily dissolved by alcohol and ether, especially if they are heated. When solid it has little taste, but its solution is extremely bitter. It exhibits more distinctly than any other of the analogous vegetable principles the properties of an alkali, restoring the colour of litmus when reddened by an acid, forming neutral salts with the acids, and decomposing the compounds of acids with the metallic oxides; it does not



however form soaps with oils. Its salts are in general soluble and crystallizable. It fuses easily, and like sulphur crystallizes in cooling; exposed to heat in contact with the air it burns, and when decomposed by destructive distillation affords a portion of carbonate of ammonia, indicating the presence of nitrogen. Its analysis by Pelletier has been already given. According to Mr Brande, it contains rather more oxygen, consisting of carbon, 72, oxygen, 17, hydrogen, 5.5, nitrogen, 5.5. Dr Thomson found no nitrogen in its composition, a result probably inaccurate. From its weak saturating power in uniting with acids, its equivalent appears to be very high, not less, as it is calculated, than 322 or 325.

As Morphine is the narcotic principle of Opium, it might be expected, when pure, to produce rapid and powerful effects; on the contrary, it is from its insolubility almost inert. When dissolved in alcohol or in acids, however, its action is much more energetic; a grain, or even half a grain, taken in this manner, occasioning violent vomiting and faintings. Its salts, from their solubility, and from being little liable to change, are usually employed as the form in which it is given. The acetate, in particular, is a very active preparation, being much more soluble than the meconate of morphine which exists in opium; this explains why vinegar increases the action of opium; on this account also, it has been recommended to add a little acetic acid to tinctures of opium, to prevent the precipitation of morphine, which sometimes takes place from them when they are exposed to a low temperature. Morphine given in these forms produces, it is found, the sedative effects of opium, and with the great advantage of not occasioning the exciting and stimulating effects of that drug, owing, it is supposed, to its being freed from another principle, *narcotine*, which exists in opium. The



celebrated black drop, so much employed as a substitute for laudanum, it is inferred, from its mode of preparation, must contain chiefly an acetate of morphine, the acetic acid being afforded by the verjuice used in preparing it, and partly formed by acetous fermentation during the process \*.

The acid with which morphine is combined in opium is the Meconic. It may be obtained from the magnesian precipitate which is thrown down in preparing morphine by Robiquet's process. This precipitate is to be dissolved in dilute sulphuric acid heated, and muriate of barytes added, which throws down meconate and sulphate of barytes. By digesting this in diluted sulphuric acid the meconic acid is separated, and by evaporation is obtained in crystals, which may be rendered more pure by sublimation.

Meconic acid has a sour and bitter taste; it reddens vegetable colours, and is readily soluble both in water and in alcohol. It melts at  $256^{\circ}$ , and may be sublimed unchanged. Its distinguishing character is that of giving a deep red colour to the salts of iron, containing the metal in the state of peroxide; it likewise gives a bright green

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\* It is generally supposed that *Battley's liquor opii sedativus*, a valuable preparation now in very extensive use, contains chiefly acetate of morphia; and it is known to possess the advantage of producing the sedative without the stimulating effects of opium. I have found that no precipitate is thrown down from the solution itself by ammonia; and my friend, Mr Aitkin, Lecturer on Materia Medica in this city, has given the solution conjoined with ammonia with much benefit in some spasmodic disorders. When the sedative solution is decolorized, however, by the action of animal charcoal, ammonia produces a white precipitate, probably morphine. It also exhibits a precipitate with acetate of lead. ED.



colour to the sulphate of copper. It produces none of the effects of opium on the animal system.

NARCOTINE. This is the other narcotic principle which exists with morphine in opium, and to which the exciting and stimulating effects of that medicine are attributed. It appears to have been the principle discovered by Derosne in opium, and which was hence long termed the Salt of Derosne. It is easily procured by treating opium repeatedly with boiling ether, which dissolves narcotine, but not the meconate of morphine, and evaporating the solution thus obtained until a saline crust is formed. This is to be dissolved in hot alcohol, the narcotine is then to be precipitated by ammonia, treated with oil of turpentine to remove a little resin and caoutchouc, dissolved in muriatic acid, and lastly again precipitated by ammonia.

Pure narcotine is insoluble in water, but is soluble in alcohol, ether, fixed oils, and acids; it does not, however, form salts with acids, nor does it change vegetable colours. By evaporating its ethereal solution, it may be obtained crystallized in rhomboidal prisms. Its composition has been already stated, whence it appears to contain nitrogen. It is supposed to be retained dissolved in the watery solution of opium, by a free acid different from the meconic, which has not yet been obtained. As it is the principle to which the disagreeable consequences accompanying the exhibition of opium have been ascribed, it has been proposed to free the extract of opium from it by repeated agitation with sulphuric ether; the narcotine it appears, however, is in this way only partially removed. Acids seem to counteract in some measure the stimulating powers of narcotine, a circumstance to which in part the superiority of the *black drop* and *liquor opii sedativus* to the common tincture may be ascribed.



## EMETINE.

A PRINCIPLE has been obtained by Pelletier from the cortical part of the root of the *Calococca ipecacuanha*, on which the emetic virtue of that root appears to depend, which has accordingly been named Emetine. To procure it, the decoction of the root is to be mixed with a large quantity of pure magnesia; the sediment is then to be washed with cold water, dried, and digested in alcohol. To purify it more completely, it is to be combined with an acid, mixed with animal charcoal, again separated by magnesia, and redissolved in alcohol, from which it may be procured by evaporation in the state of a white powder.

Emetine is not crystallizable; it has a bitter taste; it melts at  $122^{\circ}$ ; it is slightly soluble in cold, but to a greater extent in hot water; is readily dissolved by alcohol, but not by ether or oils. It restores vegetable colours reddened by acids, and combines with acids; its salts, however, cannot be made to crystallize. In a very small quantity it occasions violent vomiting.

Another emetic principle, or more probably the one that has been described in some state of combination, had been obtained previous to the discovery of the pure Emetin from Ipecacuan by Majendie and Pelletier. This they described as a browish-red substance, inodorous, of an acrid taste, soluble in water and alcohol, but not in ether, and uncrystallizable. It was precipitated, they found, from all its solutions by subacetate of lead. Half a grain of it produced vomiting, followed by sleep; six grains were said to occasion death. The pure Emetin differs from the principle thus described, in being of a white colour, in producing no change in solution of subacetate of lead, and in being equally active even in smaller quantities.



## CINCHONINE.

THE existence of this peculiar principle of Peruvian Bark, was first inferred by Dr Duncan junior, in 1803. He shewed that the febrifuge virtues of bark could not be owing, as had been supposed, to its containing gelatin, but must be attributed to a peculiar principle, which he proposed to name Cinchonin. M. Gomez, of Lisbon, whose attention had been directed to the subject by Dr Duncan's experiments, succeeded soon after in obtaining cinchonin in an insulated form. Its properties were not, however, fully ascertained till it was examined more minutely, and in a purer state, by Pelletier and Caventou. These chemists have shown, that two alkalis exist in Bark, Cinchonine and Quinine, which, like potash and soda, are distinctly different, though agreeing in a number of characters. The former exists in the *Cinchona condaminea*, or Pale Bark, which contains very little of the other; the latter, again, is present in large quantity in the *Cinchona cordifolia* or Yellow Bark, in which there is very little cinchonine: in the *Cinchona oblongifolia*, or Red Bark, they are both present.

Cinchonine may be procured in the following manner: The pale bark is boiled in alcohol until it loses its bitter taste, and the tincture evaporated to dryness in a water bath; the solid extract is then dissolved in water acidulated with muriatic acid, and the solution is boiled for a few minutes with an excess of magnesia. The precipitate which falls, after being washed with cold water, is digested repeatedly in boiling alcohol; and thus, solutions are obtained which, when evaporated, yield cinchonine in acicular crystals. Or the following more simple process of



Mr Brande may be employed : A pound of bruised bark is boiled in about a gallon of water, to which three fluid-drachms of sulphuric acid have been previously added. The bark is to be boiled a second time in half the quantity of a similar liquid, and this may be repeated till all the soluble matter is extracted. The decoctions are then mixed together and strained, and slaked lime is added, in a proportion somewhat greater than what is necessary to saturate the acid. The precipitate that falls, which is a mixture of cinchonine and sulphate of lime, is to be collected, dried, and boiled repeatedly for some minutes in alcohol, the liquid being each time poured off while hot. On evaporating these alkaline solutions, the cinchonine is obtained.

Cinchonine, thus procured, is a crystalline substance, white and translucent, very slightly soluble in cold water, and sparingly dissolved by hot water. It is readily soluble in alcohol and ether, but sparingly so in oils. Its taste is bitter, but from its insolubility, is at first scarcely perceptible ; its solution in alcohol or acids has a taste intensely bitter, with the peculiar flavour of bark. When heated it melts, and may be partly sublimed ; in its decomposition by heat ammonia is afforded. According to Mr Brande, it contains no oxygen, consisting of carbon, 79.3, nitrogen, 13.72, and hydrogen, 7.17. Pelletier and Dumas, however, found 7.79 *per cent.* of oxygen in it. Its equivalent, it is inferred, from its combinations, is about 315. It possesses alkaline properties, restoring the colour of litmus, which has been reddened by acids, and forming salts which, even with the most powerful acids, are neutral. The sulphate crystallizes in prisms ; it is soluble in four parts of water at 60°, has a very bitter taste, and possesses febrifuge virtues in an eminent degree ; being more expensive, however, than the sulphate of qui-



nine, it is little used in medicine. The muriate and nitrate are even more soluble in water than the sulphate; the former crystallizes in slender prisms. The gallate, tartrate, and oxalate of cinchonine are insoluble; from this circumstance, an infusion of galls throws down a precipitate from infusion of bark.

### QUININE.

AN alkaline principle, it has been mentioned, exists in the red and yellow Peruvian bark, analogous to cinchonine, but differing in several properties: to this Pelletier and Caventou, who discovered it, have given the name of Quinine. It may be obtained from the yellow bark by processes similar to those by which cinchonine is procured from the pale bark, or by evaporating the liquor from the red bark that remains after the crystallization of cinchonine. It does not, like cinchonine, crystallize from its alcoholic solution, but separates on evaporation in the form of a viscid mass like birdlime, which, dried cautiously in an exhausted receiver, becomes a white powder; Pelletier and Dumas, however, have succeeded in procuring it in a crystalline state by fusing it *in vacuo*, and allowing it to cool slowly. Quinine has a bitter taste, is almost insoluble in water, but is very soluble in alcohol and ether; its solutions are intensely bitter, and affect vegetable colours. Its analysis by Pelletier and Dumas has been already given: according to Mr Brande, it contains more nitrogen, consisting of carbon 73.8, oxygen 5.55, hydrogen 7.65, nitrogen 13. Its equivalent is larger than that of cinchonine, being calculated to be not less than 360; hence it is capable of saturating even less acid than that base.



Quinine combines with the acids, forming salts different from those of cinchonine. Of these, the sulphate of quinine is the most important, forming a remedy, now very extensively employed, in the cure of intermittent fevers and agues. It is formed by dissolving the pure principle in diluted sulphuric acid. By evaporation, it is obtained in fine acicular crystals, of a white colour and pearly lustre, much resembling amianthus. This salt consists of 9 parts of quinine, and only 1 part of sulphuric acid; it is less soluble in water than the sulphate of cinchonine, but has a taste equally bitter, and appears to possess even more powerful tonic and febrifuge virtues. It is indeed the only preparation of bark now used, appearing to possess all the medical properties of that valuable remedy in a concentrated form, unincumbered by inert matters which nauseate the stomach and load the bowels, and are thus liable to do as much injury as their active principles do good. Eight grains of sulphate of quinine are usually considered equivalent to an ounce of bark. The other salts of quinine are unimportant; the gallate, tartrate and oxalate are insoluble.

The Cinchonine and Quinine are combined in the varieties of Peruvian Bark, with a peculiar acid, which is also in union with lime. This was called Kinic acid by Vauquelin; but as this is a name so obviously connected with kino, the more correct appellation of Cinchonic Acid has been proposed by Dr Duncan. It may be obtained by evaporating an infusion of bark, till it becomes thick, and allowing it to stand, when the cinchonate of lime will crystallize from it in rhomboidal plates. This is to be dissolved in water, and oxalic acid added, which immediately precipitates the lime; the cinchonic acid remains in solution, and by slow evaporation is obtained in tabular



crystals. It is soluble in water, reddens vegetable blue colours, has a bitter acid taste, and is distinguished from other vegetable acids, by forming a soluble salt with lime, and giving no precipitate with the salts of silver or lead. It is from the presence of this acid that infusions of Bark redden vegetable colours.

Peruvian Bark, from which these different principles are procured, contains, according to the analysis of Pelletier and Caventou, besides cinchonine or quinine, in union with cinchonic acid, a green fatty matter, a red and yellow soluble matter, a red insoluble matter, tannin, gum, fecula, cinchonate of lime and ligneous fibre. The best test of the excellence of bark for medical purposes is the quantity of precipitate thrown down from an infusion of it by infusion of galls, as this precipitate will consist chiefly of the insoluble gallates of cinchonine and quinine.

#### VERATRINE.

AN alkaline principle was discovered in 1819, by Pelletier and Caventou, in the root of the *Veratrum album*, or white hellebore, and which has been also found in that of the *Colchicum autumnale* or meadow saffron, and in the seeds of the *Veratrum sabadilla*. This principle, veratrine, or veratria, as it has been named, has become of importance from being found to act as a valuable anodyne and specific in gout. In these plants it appears to exist in union with an excess of gallic acid. To procure it, the roots are digested in heated alcohol, the tincture evaporated to dryness, the residue dissolved in water, and evaporated till it deposits an orange precipitate; acetate of lead is then added, which throws down more coloured



matter ; any excess of acetate of lead is then removed by sulphuretted hydrogen, and magnesia added, which precipitates the veratrine ; by washing the precipitate with alcohol, and evaporating the alcoholic solution, the pure alkali is obtained.

Veratrine is a white powder, having a very acrid taste ; it is inodorous ; but when taken into the nostrils, even in very minute quantity, produces violent sneezing. An equally small quantity, taken internally, occasions alarming sickness, vomiting and purging ; and two or three grains prove fatal to animals : it is thus one of the most energetic of these principles in its action on the animal system. It is almost insoluble in water, but is readily dissolved by alcohol ; hence, a *vinum colchici* has been introduced into the London Pharmacopœia, as the best form of administering this principle. It melts at 122°, and has then a resemblance to wax ; it combines with acids, in some degree neutralizing their properties, so as to restore the colour of blue vegetables reddened by acids ; it has less alkaline power, however, than morphine or cinchonine ; its salts are not crystallizable, and are easily decomposed. Nitric acid decomposes veratrine, but does not produce with it a red colour, as with morphine and strychnine. Its composition has been already stated.

#### STRYCHNINE.

STRYCHNINE was discovered in 1818, by Pelletier and Caventou, in the fruit of the *Strychnos nux vomica*, and *Strychnos Ignatia* : it has since been detected in a nearly pure state, in the celebrated poison of the Java Upas tree ; the poisonous properties of these substances are owing to the presence of this energetic principle. It is procured in



the following manner: A portion of the raspings of the bean is heated under pressure with sulphuric ether; a green oily fluid then separates, which is to be poured off, and the residue digested with alcohol; a very bitter yellowish-brown substance is thus obtained, soluble in water and alcohol. This is to be boiled with pure magnesia, and filtered, the strychnine remaining in mixture on the filter, mixed with magnesia; it is then dissolved in hot alcohol, and is procured by spontaneous evaporation, crystallized in small white four-sided prisms. Strychnine is almost insoluble in water; its taste is, nevertheless, intensely bitter, with a slightly metallic flavour; one part dissolved even in 6 or 700,000 parts of water communicates a perceptible bitterness; it is decomposed by a temperature of 600°. Strychnine unites with the acids, forming soluble salts; its equivalent is inferred to be not less than 380. In the *nux vomica*, and St Ignatius's bean, it appears to exist in union with a peculiar acid, which has been called the ~~Igmaric~~<sup>strychnic</sup>. Strychnine is one of the most powerful and rapid vegetable poisons which have yet been discovered, producing in animals, even in quantities less than a grain, locked jaw, and other convulsive affections, ending within a few minutes in death.

## BRUCINE.

BRUCINE is a principle analogous to Strychnine, which exists along with it in the *nux vomica* and St Ignatius's bean; but being present in larger quantity in the bark of the *Brucia antidysenterica*, was named from it by its discoverers Pelletier and Caventou. It is procured by digesting the bark in ether, and then in alcohol, evaporating the latter solution, dissolving the residue in oxalic acid, again



evaporating to dryness, removing the colouring matter by alcohol, and decomposing the oxalate of brucine, which remains by lime or magnesia; the brucine by evaporation is obtained crystallized in oblique prisms. It is somewhat analogous to strychnine, but is much less active as a poison: it is also much more soluble in water than it, or any of the vegetable alkalis, requiring not more than 850 parts of cold water for solution. It is soluble in alcohol; it melts above  $212^{\circ}$ , resembling wax; it neutralizes acids, forming soluble salts.

#### PICROTOXINE.

THE bitter narcotic principle of the *Cocculus indicus*, discovered in 1819, by M. Boullay, has been named PicROTOXINE. It is procured by adding ammonia or magnesia to an infusion of the seeds, and dissolving the white precipitate which falls, in alcohol; by spontaneous evaporation, the picROTOXINE crystallizes in white four-sided prisms; these have a very bitter taste, are soluble in 50 parts of water, and still more soluble in alcohol. It does not affect vegetable colours, but combines with acids, though without neutralizing their properties; it is also dissolved by weak solutions of the alkalis.

#### ATROPINE.

FROM the leaves of the *Atropa belladonna* an alkaline principle was obtained by Dr Brandes, of considerable activity, which he named Atropine. To procure it, a decoction is made of the dried leaves, to which a hydrate of magnesia, prepared by precipitating it from the sulphate



by potash, is added; the mixture is evaporated to a dry mass, from which the atropine is extracted by boiling alcohol. Atropine when pure is a snow-white powder, tasteless, almost insoluble in water, ether, and cold alcohol; boiling alcohol dissolves it in larger quantity; the greater portion being again deposited on cooling. Atropine combines with the acids, forming soluble acids, usually containing an excess of acid. They have been little examined, from the deleterious effects, as nausea, head-ach and vertigo, which are occasioned even by the vapours that arise from them. They are particularly distinguished by the great dilatation of the pupils of the eyes which they produce.

A NUMBER of other alkaline principles have been discovered in other plants, the characters of which are not so well ascertained as those that have been described. The chief of these are the following.

DELPHINE.—This is the active principle of the *Delphinium staphysagria* or *Stavesacre*, discovered by MM. Feneuille and Lassaigue. It is separated from the malic acid, with which it is united, by making a decoction of the seeds, and boiling it with magnesia; a precipitate falls, from which Delphine is obtained, by digesting with alcohol, and evaporating the alcoholic solution. It is deposited in minute crystals, insoluble in water, having a very bitter taste, and eminently poisonous. It forms salts, soluble, bitter, and acrid.

CAFEINE. This is a principle which was discovered in 1821, by M. Robiquet, in coffee, while examining the plant, to determine whether it contained quinine, as from its febrifuge virtues he had inferred. Its properties are stated to be, that it is white, crystalline, volatile, and but slightly soluble. It does not combine with acids, but agrees with the substances which have been described, in



containing nitrogen ; indeed, the quantity of this element is remarkably large, being, according to the analysis of Pelletier and Dumas, not less than 21 *per cent.* This proportion of nitrogen exceeds what exists in any vegetable, and in most animal substances ; yet caffeine does not, like the latter, undergo the putrefactive fermentation.

DIGITALINE is the active principle of the *Digitalis purpurea*, or Foxglove, and is a very powerful poison, possessing all the properties of Digitalis in a very concentrated state. To prepare it, the leaves are digested in ether, the solution filtered and evaporated, and the residue dissolved in water ; this solution is heated with oxide of lead, filtered and evaporated, and the residuum digested in ether, which affords digitaline on evaporation. It is a brown coloured substance, deliquescent, and extremely bitter ; it restores the colour of reddened litmus, and combines with acids.

HYOSCYAMINE was obtained by M. Brandes from the *Hyoscyamus niger*, or henbane ; it crystallizes in prisms, is soluble in alcohol, and forms salts with acids ; it bears a high temperature, even it is said a red heat, without being decomposed.

SOLANINE exists in the berries of the *Solanum dulcamara*, or Woody Nightshade ; it is easily obtained by digesting the berries in alcohol, and evaporating the solution. It is a white pearly powder, having a bitter nauseous taste ; it forms salts with acids.

DATURINE is extracted from the seeds of the *Datura stramonium*, or Thorn Apple. It is obtained in small crystals, soluble in alcohol, and having great narcotic power ; it forms crystallizable salts with sulphuric, muriatic and nitric acids.



SECT. XVI.—*Of Colouring Matter, Aroma, Bitter Principle, Asparagin, Inulin, &c.*

IN concluding the history of the proximate principles of vegetables, there remain to be noticed, several of which the existence as distinct substances is doubtful, though there be some grounds for inferring them to be present in vegetables. Such are the principle of Colour or Colouring Matter, and the Bitter Principle. There are also a number of principles found in individual plants, resembling the alkaline bodies, which have just been described, but which, as they possess no power of affecting colours, or of neutralizing acids, may be with more propriety described in this than in the former section.

COLOURING MATTER. Many of the vegetable substances, used, from the richness and brilliancy of their colours in the process of dyeing, have chemical relations, whence there has appeared reason to infer the existence of a peculiar principle in which their colour resides. This supposition appears to be strengthened by the fact, that the colour of vegetables can frequently be abstracted from the vegetable matter by chemical agents, and transferred, apparently by the exertion of chemical affinities, to other substances. On the other hand, the chemical characters of colouring matter are not uniform; it is also changed or destroyed with such facility, as by the action of the sun's rays aided by humidity, by charcoal, or by chlorine, and frequently by a heat not above 3 or 400°, that it can scarcely be conceived to be a single and definite substance. To determine its nature with certainty will require farther investigations: at present the general facts respecting it only can be stated. They are interesting from their relation to the chemical arts of dyeing and pigment-making.



The colouring matter of vegetables is generally attached to some other proximate principle, and, according to the nature of this, requires to be extracted by different solvents. Frequently it resides in the extract or the gum in the plant; it is then entirely soluble in water. Sometimes it is attached to fecula, or a substance analogous to it, and in that case is insoluble in cold water, but is extracted by hot water, or by diluted acids, as by the sulphuric. Or, lastly, it may exist in resin, and then requires alcohol, an alkali, or an oil, to be dissolved.

When dissolved, the colouring matter may often be abstracted from the solvent by substances which appear to exert an attraction to it. Alumina and metallic oxides, in particular, exert actions of this kind. The former, if diffused or boiled in a coloured vegetable infusion, frequently attracts the principle, in which the colour resides so completely, that the liquor remains colourless. Or if alum be dissolved in a coloured infusion, and it be decomposed by the addition of an alkali, the argillaceous earth, in the moment of its precipitation, attracts the colouring matter with a similar effect, and forms a coloured precipitate. In like manner, if a coloured infusion be boiled with a metallic oxide, or if a metallic salt dissolved in the infusion be decomposed by an alkali, it often happens that the colouring matter is attracted by the oxide. It is apparently from similar affinities to the colouring matter that it is attracted by linen, cotton, silk, or wool, from its solutions; and even where the affinities of these are not sufficiently powerful, they may be rendered capable of attracting and retaining it, by their being impregnated with another substance, which has towards it a still stronger affinity. Lastly, the shade, and even frequently the tint of colour, are altered by chemical agents. The alkalis, acids, and various neutral and metallic salts, exert operations of this kind.



On these principles rests in a great measure the art of dyeing, the processes of which are arrangements founded on the affinities of colouring matter, in consequence of which colours are extracted, modified, transferred to the cloth, and rendered more permanent. For this view of the subject, which presents the fixation of the colour in dyeing as the effect of chemical combination, we are principally indebted to Bergman. In immersing pieces of wool and of silk in a solution of indigo in sulphuric acid, largely diluted with water, he observed, that the wool was speedily dyed, and that if the proper proportions were observed, the solution in which it was immersed was deprived of colour. The silk was dyed more weakly; it only lessened the colour of the solution, but did not abstract it entirely. In these cases he inferred that the silk exerted to the particles of the indigo a chemical affinity stronger than what existed between these particles and the diluted acid in which they were dissolved: it therefore abstracted them from the fluid. And the wool did this still more completely, as having to the indigo a still stronger attraction.

Even when the substance to be dyed has little or no attraction to the matter on which the colour depends, so as either not to be capable of abstracting it from its solvent, or of retaining it with such force as to form a permanent dye, the colour may be communicated and rendered permanent by the intermedium of a substance which, having an attraction on the one hand to the colouring matter, and on the other to the cloth or thread, shall serve to unite them. To such substances the name of Mordants, or that of Bases, introduced by Mr Henry of Manchester, is given. The principal mordants are alum, acetate of alumina, sulphate, and acetate of iron, and muriate of tin. Of these, it is not so much the entire salt, as its earthy or



metallic base, that serves to fix the colouring matter ; and in the course of the process it is often disunited from its acid. Hence the extensive application of alum, and of the solutions of tin, as mordants, from the powerful affinities of argil and oxide of tin to colouring matter. Sometimes mordants are employed rather to heighten the colour, or give it more brilliancy, or communicate a particular shade. With these different views, they are susceptible of a great variety of applications, with regard to the various dyes and the different cloths ; and the proper management of them constitutes the principal part of the art of dyeing.

The art of cloth-printing, or calico-printing, in other words, of dyeing in certain colours particular spots of the cloth, or figures impressed on it, while the ground shall be of a different colour or entirely white, depends on the same principles. A mordant, thickened with gum or starch, is applied by a stamp to the part on which the figures are to be impressed ; it thus receives a permanent dye, while the colour of the rest of the cloth after it is dyed is easily discharged, thus leaving a coloured design on a white ground. The mordants principally used in this process are the acetate of alumina and acetate of iron : these, with logwood, quercitron, and other colouring substances, giving different colours.

The formation of the vegetable pigments, or what are named Lakes, affords another exemplification of the affinities of colouring matter. The colour is extracted by its proper solvent, generally by water ; and there is added to the solution some substance capable of attracting and combining with the colouring matter, so as to form a precipitate. Thus, if alum or muriate of tin be dissolved in an infusion of brazil wood, and an alkaline solution be added, the alumina, or the oxide of tin, is precipitated, and



carries with it the colouring matter, forming therefore a lake. The most beautiful of the lakes, carmine, is prepared by this process from cochineal, which is an animal substance, formed from insects that feed on some species of *cactus*, and are supposed to derive their colour from this food.

The vegetable substances used in dyeing are extremely numerous. The Red dyes are produced chiefly by cochineal, logwood, madder, archil, brazil wood, and safflower; all these are what are called *adjective* colours, or require to be fixed by mordants, in opposition to *substantive* colours, which form permanent dyes when alone. Cochineal is fixed on cloth by oxide of tin; its natural colour is crimson, but it is used chiefly as a scarlet dye; bitartrate of potash being added to it, the acid of which changes the hue to scarlet. Archil or Litmus is obtained from some species of lichen, by reducing the plant to powder, adding potash or soda to it, and keeping it moist; it ferments, acquires a blue tint, and is then dried; as its colour is owing to an alkali, the addition of an acid restores its original red tint. The watery infusion of litmus, or paper stained with it, is used by the chemist as the most delicate test of free acids. Madder is the root of the *rubia tinctorum*, freed from the bark.

Of Yellow dyes, the richest is the quercitron bark: it is employed to give a variety of colours; thus, when alumina is used as the mordant, the decoction of this bark affords a bright yellow colour; with oxide of tin, it can be made to give any shade from pale lemon to deep orange; with oxide of iron it produces a drab colour. Saffron is another yellow dye; its colouring matter, from its changes of colour, has been called, as has been mentioned, Polychroite. Turmeric is much used by the chemist in the state of tincture, or as staining paper, as a delicate test of alkalis, which render it brown.



The combination of oxide of iron with gallic acid and tannin, already noticed as the base of writing ink, forms the chief Black dye.

Of Blue dyes, the principal is indigo, a substance of peculiar nature and properties. It is formed by an artificial process from an Asiatic and American plant, the *Indigofera*; an inferior kind has also been prepared in this country from the *Isatis Tinctoria* and *Isatis Lusitanica*, called Woad. In preparing the true indigo, the plant is cut before the time of flowering, is put into troughs with water, and pressed down. A species of fermentation is soon excited, and a quantity of aërial fluid is disengaged, partly inflammable. The water becomes turbid, and when the process is sufficiently advanced, it is drawn off into another trough, where it is kept agitated, to promote the separation of the colouring particles, adding towards the end of this stage of the operation a portion of lime-water, which favours this separation. The liquor is withdrawn into another vessel, in which the deposition is allowed to go on; and the indigo is obtained by gentle pressure in the state of a green paste, which is dried by exposure to the air, excluding the solar rays; during this process it absorbs oxygen, and acquires its blue colour. It is not well understood what the changes are that happen in this process.

Indigo is of a rich blue colour; it is light and friable, has a smooth fracture, is tasteless, and has scarcely any smell. With its pure colouring matter it contains other principles, particularly a portion of gummy and of resinous matter, earth, and oxide of iron. It yields its mucilaginous part to water, but the colouring matter is not dissolved. It is equally insoluble in alcohol or in ether. By applying heat to it cautiously, in the manner directed by Mr Crum, (*Ann. of Phil. N.S. v. 81.*) indigo may be



sublimed at about a temperature of  $550^{\circ}$ ; its vapour is of a rich violet colour, differing from that of iodine by a shade of red. The sublimed indigo condenses in flat acicular crystals, which by reflected light appear of a copper red colour, but by transmitted light appear blue: they are the purest form in which this substance can be obtained.

Indigo is acted on by the acids. The action of concentrated nitric acid, in particular, is so violent as even to inflame it; and when diluted it still acts on it forcibly, and decomposes it; along with portions of oxalic acid, benzoic acid, artificial tannin, and resin, a peculiar yellow product is formed, called Amer or Bitter Principle, which will be afterwards noticed.

Muriatic acid does not act on the colouring matter of indigo, but dissolves the oxide of iron and the earthy matter. The greater number of the other acids act on it in the same manner. Chlorine destroys its blue colour; hence indigo and chloride of lime are mutually used as tests of the quality of each other.

The proper solvent of indigo is concentrated sulphuric acid. This acid dissolves it in the cold, forming a solution at first yellow, but which in a few hours becomes blue; and this blue tint is perceptible, even when a very large quantity of water is added. The yellow colour, which at first appears, is supposed by Mr Crum to be owing to the acid abstracting oxygen and hydrogen from the indigo. In the process no separation of any product happens; but it is inferred by Mr Crum, that the constitution of the indigo is changed; that it first combines with two atoms of water, forming a substance, which, from its property of acquiring a purple colour when mixed with certain salts, he has named Phenecin; and that at length, within a period of 24 hours, it unites with two



additional atoms of water, forming a blue compound, which he calls Cerulin. The latter appears to have a property analogous to that of tannin, of forming insoluble compounds with some neutral salts, as with those of potash. Hence, by adding potash, or sulphate of potash, to the solution of indigo in sulphuric acid, a blue precipitate is thrown down, consisting of Cerulin combined with sulphate of potash. Both Phenecin and Cerulin are soluble in water; the colour of the latter is so intense, as to be perceptible when only one part of it is present in 500,000 of water. The solution of indigo in sulphuric acid is used by dyers to give the colour called Saxon blue.

Indigo exposed to heat, swells, emits vapours, and burns slowly with a white flame. From its analysis, as performed by Mr Crum, it is inferred to be composed of 16 atoms of carbon, 2 of oxygen, 4 of hydrogen, and 1 of nitrogen; its equivalent is in this way calculated to be 130. The proportion of carbon in this substance is unusually large.

Indigo seems to part readily with a portion of its oxygen, when its colour changes to green, and at the same time it becomes soluble in water and alkalis. This de-oxidation is produced by various substances, and is an essential part of the process of dyeing with it. It is commonly effected by mixing solution of protosulphate of iron with indigo diffused in water, and adding lime, by which the protoxide is separated, and in its precipitation attracts oxygen from the indigo; or it may be produced by causing the indigo to ferment mixed with vegetable matter. Sulphuretted hydrogen, and solution of sulphuret of arsenic in potash also occasion this de-oxidation. When the indigo is thus rendered soluble, the cloth is dipt into it, with which it forms a permanent combination, without requiring any mordant; and on hanging the



cloth up to the air, it re-absorbs oxygen, and its green colour changes to the original blue.

**AROMA.**—It has been supposed that a principle of odour exists in some plants which have a strong odour, and yet yield little or no essential oil. For this opinion, however, there seems to be little foundation. In general it appears that the odour of plants resides in essential oil; and this may in some cases be dissipated or changed with greater facility than in others, so that it cannot be collected.

**BITTER PRINCIPLE.**—It has been supposed that a principle exists in some of the vegetable bitters, as quassia or gentian, in which their bitterness resides. The properties, however, assigned to it, particularly its equal solubility in water and in alcohol, and its precipitation by certain re-agents, appear to prove, that what has been considered as such is a variety of extract. And were its existence established, the name that has been given to it, implying that it is the principle of bitterness, cannot with propriety be assigned to it, since so many substances possess this quality, in which it cannot be supposed to exist: thus the bitterness of opium is owing to morphia, that of Peruvian Bark to cinchonine and quinine. A Bitter Principle is artificially formed by the action of nitric acid on indigo; also on sugar and several other vegetable and animal substances. It is of a yellow colour, of an intensely bitter taste, soluble in water and alcohol, and crystallizable. From containing nitric acid, it unites with alkalis, forming crystallizable salts. Its compound with potash detonates strongly when heated.

**ASPARAGIN.**—This principle has been discovered by



Robiquet and Vauquelin in the juice of asparagus, from which it is deposited in crystals on evaporation. These crystals are white, have a nauseous taste, and are soluble in water; they give no indication either of being acid or alkaline. Its nature is not well determined, though, from yielding ammonia, it appears to contain nitrogen.

INULIN is a white powder like starch, deposited from a decoction of the roots of *Inula helenium*, or elecampane; it exists also in the *Colchicum autumnale*, and some other plants. It is insoluble in cold, but is dissolved by hot water, being deposited, however, when the fluid cools, a character which distinguishes it from starch. Its solution is somewhat mucilaginous; but the property of not being dissolved by cold water sufficiently distinguishes inulin from gum, from which it differs also in not being converted into the saccholactic acid, by the action of nitric acid. With iodine it forms a greenish coloured compound, very liable to decomposition. DALHINE, extracted from the bulbs of the *Dalhia*, is very similar to Inulin.

BASSORIN is supposed to be a peculiar principle analogous to gum; it is obtained from several species of gum, and what is called Salop consists almost entirely of it; it forms with cold water a jelly, insoluble even in boiling water and in alcohol; by long continued boiling with water it is converted into gum.

SARCOCOLL is the concrete juice of the Sarcocoll, an African plant: it has a sweetish taste; is soluble in water forming a mucilaginous solution. It is distinguished from gum by being precipitated from its solution by tannin, and by being soluble in alcohol. It appears to have a great resemblance to the saccharine matter of liquorice.

GLYCYRRH<sup>IZ</sup>INE is obtained from the Liquorice root, is soluble in water, and has a sweet taste.



OLIVILE is a principle obtained by dissolving the gum which exudes from the olive tree in alcohol, and evaporating the solution; it is obtained in acicular crystals, or in a powder like starch of a brilliant whiteness. It is dissolved readily by alcohol, sparingly by hot water, and not at all by cold water. It melts at  $158^{\circ}$  into a yellowish transparent mass like resin.

MEDULLIN is a name given by Dr John to the pith of the sun-flower: it is insoluble in water, alcohol, and ether; it is converted by nitric acid into oxalic acid. He has also given the name of POLLENIN to the pollen of tulips.

HÆMATIN is a principle discovered by Chevreul in *Hæmatoxylon campechianum*, or Logwood. It is obtained by evaporating infusion of logwood to dryness, digesting the residue in alcohol, adding water, and concentrating the solution. The hæmatine will be deposited in small brilliant reddish crystals, having a bitter, astringent, and acrid taste; it is soluble in water; gelatin precipitates it in yellow flocculi; alkalis decompose it.

PIPERIN is a principle which has been extracted by M. Pelletier from black pepper, by digesting it in alcohol, evaporating the solution, and repeatedly dissolving and crystallizing the residue; it is obtained crystallized in four-sided prisms, which are almost tasteless, the pungency of pepper residing in an essential oil.

NICOTIN, obtained by Vauquelin from tobacco, (*Nicotiana tabacum*,) by repeatedly digesting the inspissated juice in alcohol, removing portions of acetic and malic acids by saturation with potash, and distilling of the watery solution of nicotin. The principle in this state of solution is colourless and volatile; it has a very acrid taste, and possesses all the characteristic properties of tobacco, causing violent sneezing, and acting as a power-



ful narcotic poison ; it is precipitated by tincture of galls, and resembles, in general properties, the essential oils.

SENEGIN is a solid substance of a brown colour, which is obtained from the root of the *Polygala Senega*. Its taste is disagreeable, and it is soluble in alcohol, but insoluble in water. It excites violent sneezing like tobacco.

LUPULIN has been obtained by Dr Ives from the *Humulus lupulus*, or hop, and is the substance on which its narcotic properties depend. It has not been obtained in a state of purity : as procured by macerating and beating the plant, it is a yellow powder, having an agreeable aromatic odour, and a very bitter taste ; it forms about a sixth part of the plant.

SCILLITIN is procured from the root of the *Scilla maritima*, and possesses all its characters. It is soluble in water, alcohol, and ether, and has no smell, but a bitter taste.

CATHARTINE was obtained from the leaves of Senna, by MM. Lassaigne and Fenuelle, who, conceiving it to be the active principle of senna, gave it this name. It was of a reddish colour, with a bitter and nauseous taste, soluble in alcohol and water, but insoluble in ether.

RHUBARBARIN, or Rhein, is supposed to be the principle which gives the purgative power to rhubarb. It is described as being soluble in water, alcohol, and ether, with a disagreeable smell and a bitter taste.

COLOCYNTIN is a name given by Vauquelin to a bitter substance, obtained by evaporating the alcoholic solution of colocynth, and supposed to be its active principle. It is a brittle yellow substance like resin, scarcely soluble in water, but dissolved by alcohol and alkalis ; it is precipitated from these solutions by infusion of galls.

JALAPINE is a name given by Mr Hume to a resinous matter obtained from Jalap.



FUNGIN has been extracted by Braconnot from the fleshy part of mushrooms, by digesting them in hot water, to which a little alkali has been added. It is a white, soft, insipid substance with a fleshy texture, and very nutritious. Decomposed by heat it affords ammonia, and when digested in diluted nitric acid it gives out nitrogen gas. It thus approaches very closely in its characters to animal substances.

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CHAP. III.—OF THE SPONTANEOUS CHEMICAL CHANGES  
AND DECOMPOSITION OF VEGETABLE SUBSTANCES.

BESIDES the peculiar chemical changes to which the individual vegetable products are liable, there is a series of changes of which many of them are susceptible, arising from the reaction of their elements at natural temperatures, which chemists have been accustomed to class together, as forming the general process they have named Fermentation. And of this process three stages have been distinguished, marked by peculiar phenomena and products;—the Vinous Fermentation, of which vinous spirit is the product,—the Acetous, from which acetous acid or vinegar is formed,—and the Putrefactive, in which the elements are disengaged in new combinations in the elastic form. These do not always succeed each other, as it is not every substance that is capable of passing through each; but when they do, the vinous precedes the acetous, and this is terminated by the putrefactive.

SECT. I.—*Of the Vinous Fermentation.*

SACCHARINE matter is the principle more peculiarly



liable to the vinous fermentation. Sweet vegetable juices pass into it readily, as do those substances which are capable of becoming sweet, such as the fecula of grain. When the fermentation commences, the liquor, if transparent, soon becomes turbid; a kind of intestine agitation of it takes place; a quantity of aërial matter is formed, and disengaged; the temperature rises, and this continues until the fermentation is completed, which requires a longer or shorter time, according to the quality of the fermenting liquor; it then becomes transparent, depositing a sediment, and its qualities are found to be wholly changed; it has lost its bland and sweet taste, and acquired a greater or less degree of pungency: and it is capable of acting more powerfully on the living system, producing an exhilarating or intoxicating effect. The elastic fluid disengaged during the process is carbonic acid gas: the presence of atmospheric air is not necessary to this series of changes.

The process of vinous fermentation is, to a certain extent, dependent on external circumstances. Thus a due degree of temperature is required: it proceeds with most uniformity at a temperature from  $50^{\circ}$  to  $55^{\circ}$ . At  $32^{\circ}$  it is checked, and at  $60^{\circ}$ , or higher, it is too rapid, and is liable to pass, before it is completed, into the acetous stage. A certain extent of dilution with water is also necessary. If the impregnation of saccharine matter is too great, the process is retarded; if the liquor is too much diluted, it is liable to become sour as the fermentation proceeds. Lastly, the presence of what is called a *ferment* is in general required. A solution of pure sugar scarcely passes into fermentation, or does so very imperfectly, and rather forms a sour than a vinous liquor. The substance by which fermentation is excited is the scum collected on the surface of a liquor already in fermenta-



tion, or the sediment which is deposited from it, Yeast, as it is named. This added to any liquor capable of fermenting, causes the fermentation to commence, and to proceed rapidly. The nature of the matter in Yeast, by which fermentation is excited, has been the subject of research, but is yet unknown. It appears to contain nitrogen, and to bear a considerable resemblance in general characters to gluten, as it affords ammonia by destructive distillation, is liable to putrefy like animal substances, and evolves nitrogen gas when acted on by nitric acid. It is originally contained in those sweet vegetable juices which are capable of fermenting without any addition, as the juice of the grape. According to Fabroni, it is contained also in the nutritive grains; it is deposited from the juice, or from the infusion of the grain, and if added to another sweet liquor, causes it to ferment. The gluten of wheat, too, with the addition of a little tartar, by which its solubility in water is promoted, has a similar effect. After drying, yeast is still capable, when added to a sweet liquor, of exciting fermentation.

Sugar, it has often been supposed, is the only vegetable principle susceptible of vinous fermentation; the fecula of the nutritive grains passing into it, it was imagined, only after having been subjected to the process of malting, in which it is changed into saccharine matter. It is now known, from the practice of the spirit-distillers of this country, that this preliminary process of malting is not indispensable; they always add a portion of unmalted to malted grain; the former is often even in larger quantity than the other; and the infusions of this pass into the vinous fermentation on the addition of yeast. Fourcroy and Vauquelin have shewn, that unmalted grain alone can be made to ferment, and afford a liquor, which, by distillation, gives alcohol. As fecula consists of the same prin-



ciples as sugar, differing only in the proportions, it is not difficult to conceive, that by the series of changes which fermentation establishes, it may afford the same product.

What has been called the *panary fermentation*, which dough mixed with yeast undergoes, and which is necessary to the formation of good bread, it has been supposed, is, in fact, a species of vinous fermentation, the saccharine matter of the flour being converted, as would appear, into alcohol and carbonic acid, which, in escaping, give the spongy texture to bread.

The theory of the vinous fermentation has been developed by the researches of Lavoisier, Saussure, and Gay-Lussac. The ultimate result of the process is, the formation of a peculiar principle, volatile and inflammable, which can be obtained, by distillation, from the fermented liquor; this diluted, and with some degree of intermixture, forms the common spirituous liquors; and in its pure form, ALCOHOL. Sugar being a compound of carbon, hydrogen, and oxygen, carbonic acid gas being disengaged during fermentation, and no oxygen being absorbed from the air, Lavoisier supposed that the whole process consists in part of the oxygen and carbon of the sugar combining, and forming the carbonic acid, and its hydrogen, with the remaining carbon and oxygen, forming the alcohol: hence, if carbonic acid and alcohol could be again united, they would form sugar. This opinion, it now appears, is perfectly just. Alcohol, it has been shown by Saussure, consists of two atoms of carbon, one of oxygen, and three of hydrogen. Sugar, as has been stated, is composed of one atom of carbon, one of oxygen, and one of hydrogen; or multiplying the latter by 3, to equalize the quantities of hydrogen, the following is their relation:



Sugar consists of Carbon 3 atoms, Oxyg. 3 atoms, Hyd. 3 atoms.  
Alcohol consists of Carbon 2 atoms, Oxyg. 1 atom, Hyd. 3 atoms.

Hence, it appears, that Alcohol differs from Sugar in containing one atom less of carbon, and two less of oxygen; that is, in wanting one equivalent of carbonic acid. According to this view, 45 parts of sugar will yield 23 of alcohol, or 100 pounds of sugar will consist of 51.34 pounds of alcohol, and 48.66 of carbonic acid.

From the saccharine juices of fruits, wines are formed by fermentation; those from the juice of the grape are greatly superior to the others in strength and flavour. The cause of this superiority is, that the vegetable acid existing in the grape is the tartaric, combined with potash, forming the bitartrate of potash. This salt is insoluble in alcohol; hence, during the fermentation, it is in a great measure deposited, and the wine retains little acidity to injure the flavour, or prove injurious to the stomach. But in the currant, the gooseberry, and most other fruits, the acids present are the citric and malic: these are soluble both in water and alcohol, and the latter forms soluble salts with almost every known base; hence the wines from these fruits cannot by any means be freed from acid. The sour taste is, indeed, partly concealed by an addition of sugar; and to prevent this from fermenting, a quantity of brandy is added; still the acid is present, and is hurtful to the stomach; and when the sugar is removed by fermentation, the sour taste is very perceptible. By fermentation, liquors somewhat analogous to wine are formed from the nutritive grains, as porter, ale, and beer, which retain, however, portions of mucilaginous and extractive matter: they generally contain free acid, the taste of which is disguised by sugar, or by bitter herbs, as hops. All these fermented liquors afford spirituous liquors by distillation, the wine of the grape yielding the purest and strongest product.



There has been considerable difference of opinion as to the state in which alcohol exists in wines. It had been generally supposed, that the alcohol procured from them by distillation had pre-existed in them; but some chemists considered it more probable, that it was produced in the process of distillation by reaction between the different elements, favoured by the heat. Mr Brande, however, has proved that the former is the correct supposition; by obtaining the alcohol from wine, without applying heat. His method was to add a solution of subacetate of lead, (Goulard's extract,) to the wine, which occasions a precipitate to fall down, consisting of the colouring matter and tartaric acid of the wine combined with the oxide of lead. On withdrawing the clear liquor above, and adding dry carbonate of potash, alcohol rises to the top, and its quantity is found to be nearly the same as that obtained by distillation. The following table exhibits the average proportions of alcohol, which Mr Brande obtained from different wines :

Wine.	Proportion of Alcohol per cent. by measure.	Wine.	Proportion of Alcohol per cent. by measure.
Lissa, - -	25.41	Roussillon, - -	18.13
Raisin wine, - -	25.77	Grape wine, - -	18.11
Marsala, - -	25.09	Malaga, - -	17.26
Port, highest, - -	25.83	White Hermitage, - -	17.43
lowest, - -	19	Claret, highest, - -	17.11
average, - -	22.96	lowest, - -	12.91
Madeira, highest, - -	24.42	average, - -	15.10
lowest, - -	19.24	Burgundy, average, - -	14.57
average, - -	22.27	Hock, - -	12.08
Cape Madeira, - -	20.51	Vin de Grave, - -	13.37
Currant wine, - -	20.55	Champagne, (still) - -	13.80
Sherry, highest, - -	19.81	(sparkling) - -	12.80
lowest, - -	18.25	red, - -	12.56
average, - -	19.17	Frontignac, - -	12.79
Teneriffe, - -	19.79	Red Hermitage, - -	12.32
Constantia, white, - -	19.75	Cotie Rotie, - -	12.32
red, - -	18.92	Gooseberry wine, - -	11.34
Lisbon, - -	18.94	Tokay, - -	9.88
Calcavella, - -	18.65	Elder wine, - -	8.79



Wine.	Proportion of Alcohol per cent. by measure.	Wine.	Proportion of Alcohol per cent. by measure.
Cider, highest,	- 9.87	London porter,	- 4.20
lowest,	- 5.21	Ditto, small beer,	- 1.28
Perry,	- 7.26	Brandy,	- 53.39
Ale, (Burton)	- 8.88	Rum,	- 53.68
(Edinburgh)	- 6.20	Hollands,	- 51.60
(Dorchester)	- 5.56	Scotch Whisky,	- 54.32
Brown Stout,	- 6.80	Irish ditto,	- 53.90

These results, stated by Mr Brande, present the singular circumstance, that the quantity of alcohol existing in many wines is much greater than what would be inferred from their exciting effects; port wine, for instance, yielding nearly half the quantity of alcohol that is present in brandy, though the intoxicating power of the latter is much more than double that of the former. It would appear from this, that the alcohol in wine is combined with other principles which modify and diminish its activity. The experiments of Mr Brande have been confirmed by those of Gay-Lussac, who followed the same method, only using litharge, as preferable to the subacetate of lead. Gay-Lussac has also added the important fact, that the alcohol may be separated from wine by distilling it *in vacuo*, at the temperature of 60°,—a result free from all ambiguity to which the application of heat might give rise.

Alcohol is procured from spirituous liquors by repeated distillation; being volatile, it is thus freed from the water with which it is diluted. The process is usually facilitated by certain additions. After the spirituous liquor has been once distilled, by which it is freed, not only from a considerable portion of water with which it is diluted, but also from the oily or extractive matter which gives it flavour, there is added to it  $\frac{1}{12}$ th of its weight of the pearl-ash of commerce, previously exposed to a red heat. This attracts a considerable portion of water, which forms a



dense solution, which subsides; the spirit above is poured off, and distilled with the heat of a water bath. The alcohol thus procured has still water combined with it. It may be obtained, more concentrated, by repeated distillations with a very gentle heat, from potash, from dry lime, barytes, or alumina, or from fused chloride of calcium. An easy method of increasing the strength of alcohol is to suspend it inclosed in a bladder, and exposed to the air, when the water will exude through the bladder, leaving the alcohol.

Alcohol, as obtained by the usual process, is of the specific gravity of from 0.835 to 0.825, in which state it is sufficiently adapted to many of the uses, depending on its chemical agency, to which it is applied. It has been brought, by using potash, to the specific gravity of 800, 798, or even 796, at the temperature of  $60^{\circ}$ ; when of the usual specific gravity, 0.820, it contains above 10 *per cent.* of water, which may be abstracted in its higher rectification. The specific gravity of its vapour, according to Gay-Lussac, is 1.613.

Alcohol is colourless and transparent; its odour is fragrant, and its taste pungent; it acts powerfully on the animal system, producing exhilaration and intoxication.

Alcohol retains its fluidity at the lowest temperatures which can artificially be produced, not being frozen even at  $-91$ . Mr Hutton affirmed that he had frozen alcohol; but as he published no account of the manner in which it was done, the fact is doubtful.

Alcohol is highly expansible from heat, and volatile; it evaporates quickly on exposure to the air, boils at  $173^{\circ}$ , or  $176^{\circ}$ , and at  $56^{\circ}$  *in vacuo*. Its vapour transmitted through an ignited tube is decomposed, a large quantity of carburetted hydrogen gas with carbonic acid is formed, and charcoal is deposited. In this way its analysis



was performed by Saussure, apparently with much accuracy: he found it to consist of carbon 51.98, oxygen, 34.32, and hydrogen, 13.7; whence it is inferred to be composed of two atoms of carbon, 12, one of oxygen, 8, and three of hydrogen, 3; its equivalent is therefore 23. Or, considering its constitution in reference to Gay-Lussac's theory of volumes, alcohol will consist of 2 volumes of vapour of carbon, 3 volumes of hydrogen, and half a volume of oxygen; or it may be conceived to be formed by the union of equal volumes of olefiant gas and watery vapour condensed into half their united bulk; if this be the case, by adding the specific gravity of olefiant gas, 0.9722, to that of watery vapour, 0.625, the result, 1.597, should be the specific gravity; and this accordingly agrees closely with what was ascertained experimentally by Gay-Lussac.

Alcohol is highly inflammable. It kindles, when the temperature is not much above  $300^{\circ}$ , when in contact with atmospheric air, and burns with a blue lambent flame, without any smoke, and, when pure, without any residuum, affording merely water and carbonic acid gas; and the quantity of water that is condensed exceeds even the weight of the alcohol consumed, so large a portion of oxygen being consumed in the combustion.

Alcohol combines with water in every proportion; and although the properties are not much modified, the combination is marked by the specific gravity of the compound not being the mean of the specific gravities of the two fluids. It is greater than the mean, from the condensation that takes place. This condensation is accompanied with a diminution in the capacity for caloric, and hence with a rise of temperature of not less than  $20^{\circ}$  when equal parts are mixed. Alcohol diluted with an equal weight of water forms what is named Proof Spirit. The density of



this is 0.916 ; but what is commonly called proof spirit is usually not lighter than 0.920 ; and that directed in the Pharmacopœias to be used in making preparations is to be of the strength only of 0.930 or 0.932. Spirits lighter than that is stronger than the standard, are said to be above proof, and those which are more dilute to be below proof.

In consequence of its affinity to water, alcohol precipitates many of the neutral salts from their aqueous solutions. There are others which it does not precipitate, and which it even dissolves. In particular, it exerts a strong affinity to muriate of magnesia ; it also dissolves muriate of lime readily, and the nitrates of magnesia, alumina, lime, and ammonia. It unites with sulphur, iodine, and phosphorus, and dissolves the alkalis, potash, soda, lithia, and ammonia.

The acids combine with alcohol, and some of them decompose it, forming a particular order of compounds, the Ethers, as they are named, to be immediately considered.

Alcohol is the solvent of a number of vegetable principles, as sugar, resin, extract, camphor, essential oil, and several of the acids ; hence it extracts the medicinal powers of many vegetables, and is employed in pharmacy, either in its pure form, or diluted, to form Tinctures. Solutions of resinous substances in it form Varnishes.

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The action of the more powerful acids on alcohol is peculiar, and gives rise to an order of compounds, important from their chemical properties. These have been distinguished by the generic appellation of ETHERS. They differ in their qualities as produced by the different acids ; but they also agree in the possession of certain general properties ; they are highly volatile, odorous, pungent, and inflammable ; miscible with water, and capable of



combining with alcohol in every proportion. **SULPHURIC ETHER**, produced by the action of sulphuric acid on alcohol, is the one which has been longest known to chemists.

To prepare sulphuric ether, concentrated sulphuric acid is poured on an equal weight of alcohol in a retort; and after they are thoroughly mixed by gradual agitation, heat is applied by the medium of a sand-bath, a large receiver being adapted to the retort, carefully luted, and kept cool by water. Distillation commences when the temperature is raised to  $208^{\circ}$ , and a colourless liquid condenses in the receiver. When it amounts to about half the quantity of alcohol that had been employed, the heat is withdrawn. The residual liquid is of a dark brown or black colour. If a fresh portion of alcohol, not more than half of the first quantity, be added to it when it is cold, an additional portion of ether will be procured by a new distillation. Mr Brande directs that the heat should be applied as rapidly as possible in this process, and raised considerably above  $212^{\circ}$ ; as in this way the largest quantity of product will be obtained. Mr Phillips, on the other hand, states that the strongest ether is procured by a slow distillation.

The ether condensed in the receiver by this process is weak from the intermixture of water, and is usually also impure from the presence of a portion of sulphurous acid. It is rectified by agitating it with subcarbonate of potash, or muriate of lime, and distilling it a second time by a very gentle heat, putting into the retort from which it is distilled a small quantity of black oxide of manganese. Ether is rendered still purer by repeated agitation with water, which abstracts a portion of alcohol that is usually mixed with it. This process, called the washing of ether,



is requisite in preparing it for some purposes, as for dissolving caoutchouc.

There are some other products disengaged in the process by which sulphuric ether is formed. Towards the end of the distillation, a yellow oily-like fluid condenses, which the chemists have named *Ethereal Oil*, or *Oil of Wine*. This has been supposed by some to be a compound of ether and sulphurous acid, while others have regarded it as of a composition analogous to ether, but containing a larger proportion of carbon. Mr Hennel and Mr Faraday have investigated its composition, and consider it to be a compound of 2 atoms of sulphuric acid, 8 of carbon, and 8 of hydrogen; that is, of two atoms of sulphuric acid, and four of olefiant gas. It is neutral, or exhibits no indication of acidity. When heated, two atoms of olefiant gas are evolved, and a peculiar compound remains, termed *Sulphovinic acid*. This is obtained more easily by mixing equal weights of sulphuric acid and alcohol, allowing the mixture to remain for half an hour, and then precipitating the sulphuric acid by carbonate of lead; the sulphovinic acid remains in solution, and on the addition of a base, salts called *Sulphovicates* are formed. It is supposed to consist of two atoms of sulphuric acid, four of carbon, and four of hydrogen; that is, of one atom of sulphuric acid and one of olefiant gas. Towards the end of the process for preparing ether there is disengaged a considerable quantity of olefiant gas.

The theory of the formation of ether is now satisfactorily developed. Fourcroy and Vauquelin, from an experimental investigation of the process, inferred, that the sulphuric acid does not suffer decomposition; they supposed that it acts merely by abstracting water, or rather its elements, oxygen and hydrogen, from the alcohol, which is thus converted into ether. This view is now known to



be one perfectly just ; though it would appear, that in the first part of the process, a portion of sulphuric acid abstracting olefiant gas from alcohol, becomes sulphovinic acid. Ether, from the analysis of Saussure and Gay-Lussac, is inferred to consist of two atoms of olefiant gas, and one of water. Alcohol, it has been mentioned, is composed of one atom of olefiant gas and one of water ; hence by abstracting one atom of water from two atoms of alcohol, ether will be formed. The other phenomena observable in the process accord with this supposition. The sulphuric acid, it is known, has a strong affinity to water ; and, during the operation, it appears to suffer no other change than by becoming diluted, so that it is capable of converting several successive portions of alcohol into ether, until it becomes too weak ; moreover, no trace of the acid can be discovered in the ether formed ; the disengagement of olefiant gas, at the end of the process, is also easily explained, by supposing, that when the greater part of the alcohol is decomposed, the acid acts more powerfully, and abstracts the whole of its water of composition. It is also found that other acids, which have a strong affinity to water, convert alcohol into ether, as well as the sulphuric.

Sulphuric ether is a fluid extremely light ; its specific gravity, when it is highly rectified, being so low as .716, and it is said has been obtained even at 0.700. It is colourless and transparent, has a pungent taste, and a penetrating, rather fragrant odour. It is highly volatile, evaporating rapidly at natural temperatures: the specific gravity of its vapour is calculated to be 2.5694 to air as 1. It boils under the usual atmospheric pressure at  $98^{\circ}$ , and, *in vacuo*, boils at a temperature even below  $0^{\circ}$ . In its spontaneous evaporation, it absorbs a considerable quantity of caloric, so as to produce intense cold, sufficient



even, as has been mentioned, to freeze mercury. It congeals at  $-47^{\circ}$ . It is inflammable, burns with a clear white flame, and without smoke, producing by its combustion water and carbonic acid. Its vapour, diffused in atmospheric air or oxygen gas, explodes when kindled; if diffused through chlorine, a spontaneous explosion happens. As ether consists of two volumes of olefiant gas, 28, and one of water, 9, its equivalent is 37. When a coil of red hot platina wire is suspended in the vapour of ether, the metal, as has been stated, (vol. i. p. 445,) continues red hot from invisible combustion. While this continues pungent fumes arise, which may be condensed into an acid liquid. This was supposed by Mr Daniell to be a peculiar acid, which he named the Lampic; but he has since found it to be disguised acetic acid. It has been shewn by M. Planche and Gay-Lussac, that if a vessel partially filled with ether be exposed to the light, and frequently opened, a portion of the ether is converted into acetic acid.

Sulphuric ether is soluble in water, requiring about 10 parts for its solution. It dissolves in alcohol in every proportion. On the fixed alkalis or earths it exerts no action: with ammonia it combines by distillation. It dissolves sulphur and phosphorus in small proportions; and it resembles alcohol in the solvent operation it exerts on a number of the vegetable proximate principles.

NITRIC ETHER is formed by the action of nitric acid on alcohol; but, from the violence of this action, the process is difficult, and requires to be conducted with much caution. The method which, upon the whole, answers best, is to add nitrous acid by degrees to an equal weight of alcohol, in a retort, allowing the mixture to stand for some time after each addition, then to apply heat cau-



tiously, connecting the retort with a range of receivers, kept cool; nitric ether is formed and volatilized, and is condensed by passing the gaseous product through water, or through a solution of muriate of soda in the receivers. It floats above the liquor, and is purified from any free acid by agitation with lime, and a second distillation with a gentle heat.

The theory of the formation of nitric ether is more obscure than that of sulphuric ether. It appears that the acid and alcohol mutually decompose each other, portions of oxalic and acetic acid with water being formed, nitrogen, carbonic acid, and nitrous oxide being disengaged. Thenard farther found, that after the free acid of the nitric ether at its first distillation is abstracted by lime, acidity is regained, when it is kept for some time either with or without the access of air; and this arises from the production of nitric and acetic acids, the elements of which must therefore exist in the composition of nitric ether. It is hence concluded, that nitric ether consists of nitrous acid combined with alcohol, part of the oxygen of the nitric acid employed having combined with portions of the carbon and hydrogen of the alcohol, giving rise to the formation of water and carbonic acid, and the evolution of the nitric oxide, nitrous oxide, and nitrogen gases.

Nitric Ether has an odour strong, but less fragrant than that of sulphuric ether; it is heavier than alcohol, but more volatile, and highly inflammable. Its volatility is so great that it instantly evaporates when poured from a bottle, and it boils at  $70^{\circ}$  under the usual atmospheric pressure; it requires 50 parts of water for its solution, but combines with alcohol in every proportion. 100 parts of it are composed of 14.49 of nitrogen, 28.65 of carbon, 48.52 of oxygen, and 8.54 of hydrogen.

When a smaller portion of nitric acid is added to alco-



hol than is sufficient to convert it entirely into ether, a product is obtained on distillation, having a fragrant odour, which has been named Spirit of Nitrous Ether, and has been regarded as nitric ether largely diluted with alcohol with a portion of free acid.

**MURIATIC ETHER.**—The action of muriatic acid in its common state on alcohol is inconsiderable; but when the acid gas is transmitted directly through alcohol, and the impregnated liquor distilled, a proper ether is formed. An improved process, given by Thenard, consists in mingling equal parts by measure of alcohol and concentrated muriatic acid in a retort, exposing the retort, supported on a grate of iron, to the direct fire of a common furnace, there being connected with the retort a large bottle half-filled with water, with a tube of safety inserted, and to which a bent tube is adapted, terminating under an inverted phial filled with water: when the liquor is brought to boil, the muriatic ether is disengaged, in the gaseous form, and is collected in the phial. This ether may also be formed, it is said, by distilled alcohol with chloride of tin: the direct action of chlorine gas on alcohol produces an oily rather than an ethereal product. Muriatic ether gas is colourless, has a strong ethereal smell, and a saccharine taste. At a temperature below  $50^{\circ}$ , it condenses into a liquid, which retains the same taste and odour, and is limpid; its specific gravity is 0.874. It evaporates rapidly, producing much cold. Cooled to  $-22^{\circ}$ , it does not congeal. Water absorbs its own volume of the gas. Muriatic ether has no sensible acidity, nor can muriatic acid be detected in it by the delicate tests of nitrate of silver and proto-nitrate of mercury; yet when it is kindled, a large quantity of muriatic acid is disengaged; and this acid is also slowly evolved in it when it is kept for some time. From the experiments



of Robiquet and Colin, this ether is inferred to consist of equal volumes of muriatic acid and olefiant gas, combined probably in the state of their elements, without condensation.

HYDRIODIC ETHER has been obtained by Gay-Lussac, by distilling equal parts by measure of alcohol and hydriodic acid. It does not redden litmus; it boils at  $148^{\circ}$ ; it soon acquires a rose colour from the evolution of a portion of iodine.

PHOSPHORIC ETHER is obtained by heating a mixture of alcohol and concentrated phosphoric acid: a portion of unchanged alcohol first passes over, and then an ethereal fluid, which may be purified by redistillation with lime. It has the odour and specific gravity of sulphuric acid, is highly volatile and inflammable, and in burning affords no trace of sulphuric acid.

FLUORIC ETHER is procured by heating in a leaden retort equal parts of fluor spar, alcohol, and sulphuric acid. On distilling the product a second time from potash, an ethereal liquid is obtained, resembling sulphuric ether, and which may perhaps have been formed by the action of the sulphuric rather than of the fluoric acid.

ACETIC ETHER is obtained by distilling repeatedly alcohol from concentrated acetic acid, (procured from acetate of copper): it gradually acquires an ethereal odour, and after the third distillation and rectification by an alkali, it forms a proper ether. Thenard found, that if the distillation be repeated ten or twelve times, the acetic acid is almost entirely decomposed, and the alcohol is converted into ether. In this conversion he supposes that the elements of the alcohol combine with those of the acid, or with the acid itself, without any other product being formed. The odour of acetic ether is grateful; its specific gravity is .866; it evaporates on exposure to the air,



and boils at  $123^{\circ}$  ; it is soluble in water, requiring scarcely eight parts for its solution : if to this solution potash is added, the odour and taste of the ether disappear, diluted alcohol is obtained by distillation, and acetate of potash remains in the retort. In burning, acetic acid is deposited, though the ether itself is free from all acidity. It is regarded by Thenard as a compound of acetic acid and alcohol.

The other vegetable acids do not act on alcohol, but if a mineral acid be added at the same time, ethereal products are formed, into the composition of which the vegetable acid enters, without any of the mineral acid. These are regarded by Thenard as compounds of the vegetable acids with alcohol.

## SECT. II.—*Of the Acetous Fermentation.*

WHEN the vinous fermentation has ceased, if the liquor be kept under the same circumstances, with the admission of the atmospheric air, it begins to suffer another change. It loses its vinous fragrance and pungency, and becomes sour. When this process is completed, an acid liquor is formed, Vinegar, the acid of which in its pure form is denominated the Acetic, and the process by which it is formed is named the Acetous Fermentation.

Every substance susceptible of the vinous is susceptible of the acetous fermentation, and this even without having previously become perfectly vinous; and there are substances incapable of the former, which undergo the latter, as vegetable infusions, or juices containing much mucilage with a little saccharine matter. Alcohol by itself is incapable of this change, and even to a certain extent counter-



acts it; hence strong vinous liquors do not so readily become sour as those that are weak.

The action of a ferment, as yeast, appears to be necessary to excite the acetous fermentation. The admission of the atmospheric air is indispensable; and its oxygen is absorbed, and appears to combine with carbon from the fermenting liquor, so as to form an equivalent portion of carbonic acid. Lastly, a due degree of temperature is required, the fermentation taking place slowly when the temperature is below  $60^{\circ}$ , and being accelerated when it is raised to  $70^{\circ}$ . When it is rapid, there is an intestine motion in the liquor, as there is in the vinous fermentation; it is turbid, its temperature rises, and there is a disengagement of elastic fluid. When it is complete, these appearances subside, and the liquor, depositing a considerable sediment, becomes clear.

There is still obscurity with regard to the theory of the acetous fermentation. As the oxygen of the air is absorbed, it might be supposed that the alcohol combines with this, forming the more highly oxygenated product, acetic acid; but if the observation be a correct one, that a quantity of carbonic acid is generated equivalent to the oxygen absorbed, this opinion cannot be maintained. The true theory can be developed only by farther investigation. The agency of the ferment is as inexplicable in this as in the vinous fermentation; and little or none of it seems to be consumed in the process.

Vinegar is of different degrees of purity and strength, according to the materials from which it is prepared; that from wine is purest and strongest; prepared from unrefined sugar, or from infusions of malted grain, it contains a portion of vegetable matter, which renders it liable to spontaneous decomposition. Along with the acetic



acid, which is its base, vinegar always contains a portion of extractive matter, which gives it colour, and frequently also portions of malic and tartaric acids.

To obtain the pure acid, the easiest method is distillation. It passes over with a portion of water, and is thus freed in some degree from the extractive matter, and from the other acids, care being taken not to continue the distillation too long, nor to raise the heat too high, as the vinegar is liable to acquire an empyreumatic odour. Distilled vinegar is however weak, and not very pure, and hence other processes are employed to obtain acetic acid in a concentrated state.

Its concentration can be effected by freezing, the water congealing, and the acid remaining uncongealed; and by repeating the operation with greater degrees of cold, a very strong acid can be obtained. Another method is to expel the acid from its saline compounds. Thus, if acetate of potash or of soda, rendered as dry as possible, be exposed to heat with concentrated sulphuric acid, the sulphuric acid combines with the base of the salt, and the acetic acid is disengaged: by re-distilling with a little oxide of manganese, it is rendered quite pure. It is also obtained by exposing what is called distilled verdegris, which is the binacetate of copper, to a heat gradually raised; the acid is volatilized, and is obtained in a very concentrated state.

As thus obtained, it is much more volatile and pungent than distilled vinegar, whence it was supposed to be a stronger acid, and was called the Acetic, while vinegar was termed Acetous acid. It is now known that there is no other difference between them than that of the latter being more dilute and less pure. In the distillation of acetic acid from the metallic acetates, there appears to



be some decomposition produced towards the end of the process, in consequence of which a product of a spirituous nature is formed, which, when it is obtained by neutralizing the acid and distilling, is found to be lighter than alcohol, volatile and inflammable. This has been termed by MM. Derosnes by the name of Pyro-acetic Ether. It diminishes the specific gravity of the acid, and is perhaps the cause of its inflammability and pungent smell.

There are some other processes in which this acid is formed. It has already been remarked, that in the decomposition of wood by heat, an empyreumatic acid called Pyroligneous Acid is obtained. This is impure acetic acid; by filtrating it through animal charcoal, (prepared by calcining beef or mutton bones in close vessels,) it is completely deprived of the colour, taste and smell derived from the impurities, and becomes a very strong acetic acid. It is now extensively used for chemical purposes, in pharmacy and in several of the arts.

Acetic acid has an odour fragrant and penetrating; it is caustic, and, even when largely diluted, has a sour taste. It congeals at a low temperature, and when very concentrated may be obtained in crystals, even at common temperatures: these consist of one atom of acid and one of water. It is very volatile, its odour being quickly diffused when it is exposed to the atmosphere, and by a moderate heat it rises entirely in vapour: this vapour kindles on the approach of a burning body. The real acid is inferred to consist of four atoms of carbon, 24, three of oxygen, 24, and two of hydrogen, 2; its equivalent is therefore 50, which agrees with the number deduced by Dr Thomson from the analyses of some of its salts.

Acetic acid combines with the alkalis and earths, forming salts, which are named ACETATES. They are in ge-



neral soluble in water, and are not easily crystallized; they are destroyed by heat.

ACETATE OF POTASH, formed by saturating distilled vinegar with potash, is obtained by evaporation of its solution, in the state of a white foliated mass; or if the evaporation is carried to a less extent, small prismatic crystals form slowly. This salt is extremely deliquescent, is soluble in little more than its weight of water, at  $60^{\circ}$ , and is also soluble in alcohol. ACETATE OF SODA, usually obtained by saturating pyroligneous acid with chalk, and then adding sulphate of soda, crystallizes in slender prisms, which are deliquescent, and are soluble in 3 parts of water, at  $60^{\circ}$ : at a temperature of  $600^{\circ}$ , it is decomposed, and yields concentrated acetic acid. ACETATE OF AMMONIA, by evaporation with a very gentle heat, may be obtained in acicular prisms. The Earthy Acetates are all soluble, and, by evaporation, afford either a gelatinous mass, or acicular crystals. ACETATE OF ALUMINA, formed by adding acetate of lead to sulphate of alumina, is an important mordant in dyeing.

The Metallic Acetates are likewise, in general, soluble and crystallizable: those applied to any use are the acetates of quicksilver, copper, and lead.

Acetate of quicksilver is prepared by decomposing a solution of proto-nitrate of quicksilver by adding a solution of acetate of potash; the acetic acid combines with the protoxide of quicksilver, and the acetate is copiously deposited in scales of a white colour, and brilliant silvery lustre. This salt has been used as a mild mercurial preparation.

Copper forms different combinations with acetic acid. The verdigris of commerce is an impure acetate of the peroxide, prepared by stratifying copper-plates with the husks of the grape, after the expression of the juice, and



moistening them occasionally with weak vinegar. The copper is oxidated, and combines with the acid; this forms a crust on the surface of the metal; it is scraped off and dried, and is of a light green, sometimes of a blue colour; when dissolved in water it is resolved into an insoluble subacetate, composed of one atom of acid and two of peroxide, and a soluble binacetate. This binacetate is more easily obtained by dissolving verdigris in distilled vinegar, and evaporating the solution; it is in octohedral crystals, aggregated, of a deep green colour, soluble in water and in alcohol. Both the acetate and binacetate are used as pigments, also in the processes of dyeing, and in medicine as escharotics.

Acetic Acid forms also different combinations with lead. Cerusse, or white lead, prepared by exposing plates of lead to the vapours of vinegar, had been supposed, from its mode of formation, to be an acetate, but is a carbonate of lead. When this is dissolved in distilled vinegar, and the solution evaporated, the acetate of lead is obtained, which, from its sweet taste, has been named Sugar of Lead, and which is used in medicine and in several of the arts. Its crystals are acicular prisms, semi-transparent, of a white colour, with a silky lustre, slightly efflorescent, and soluble in 3 parts of water at  $60^{\circ}$ ; they contain three atoms of water. The subacetate of lead is prepared by boiling vinegar on litharge; it does not crystallize readily, and its crystals are plates; it is in fact a trisacetate of lead, containing three atoms of base; what is named Goulard's Extract is a solution of it. Carbonic acid gas, transmitted through the solution, decomposes the salt, forming carbonate of lead. The composition of these different acetates will be found in the table in the Appendix.



SECT. III.—*Of the Putrefactive Fermentation.*

THE process of putrefaction, in animal matter, consists, in the formation, from new combinations of its elements, of products offensive in their odour, which escape in the aërial form. Few vegetable substances can be said to be liable to it, yet they undergo a species of decomposition somewhat analogous, in which a similar evolution of gaseous products takes place, so that only the saline and earthy matter of the vegetable substance at length remains. To this the name of the Putrefactive fermentation has been given.

Those vegetable products, which are either soluble in water, or imbibe it, are those more peculiarly liable to this series of changes; and the same circumstances favour it which favour the other kinds of spontaneous decomposition, particularly a moderately high temperature, as between  $50^{\circ}$  and  $90^{\circ}$ , and the access of the air. The elastic products disengaged are compounds of carbon and hydrogen, and carbonic acid; the former, according to the researches of Saussure, appearing principally when the action of the atmospheric air is excluded by the substance being immersed under water; the latter when the air is admitted, the oxygen of the air combining with the carbon of the vegetable substance, to form the carbonic acid, and with its hydrogen forming water. There is no sensible production of ammonia, or of gases containing sulphur and phosphorus, the evolution of which more particularly characterises animal putrefaction, a difference arising from the absence of these elements, and of nitrogen, in the composition of vegetable matter. Those few vegetable products, however, which contain them, present results in their ultimate decomposition similar to those of animal substances.



Carbon being in general the basis of vegetable matter, it frequently remains, forming an inert residuum after the decomposition has proceeded to a certain extent, constituting what is named Vegetable Mould. This, when the air is excluded, is scarcely liable to any farther change, there being no other principles to react on it with sufficient force. If the air is admitted, however, its oxygen acts on the carbonaceous base, and forms carbonic acid; this abstraction of carbon allows part of the oxygen and hydrogen of the mould to combine and form water, and by these progressive changes, the decomposition is at length rendered complete, and nothing remains but the saline, earthy, and metallic substances, originally contained in the vegetable matter.

It appears, however, that often from the operation of circumstances, probably the exclusion of the atmosphere, and the presence of pressure, the decomposition does not proceed beyond the accumulation of this carbonaceous residuum; the former circumstance removing the agency of oxygen, the latter preventing the formation of elastic products: and from the process conducted under these circumstances, and on vegetable matter originally composed principally of carbon, as wood, have probably principally originated the different varieties of bitumens and coal, the origin of which from the vegetable kingdom, it has already been stated, can be often traced.



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## BOOK IX.

### OF ANIMAL COMPOUNDS.

THE chemical history of animal substances may, like that of the vegetable products, be considered under three divisions;—the first comprising what relates to their formation; the second including the details of their individual chemical qualities and combinations; and the third embracing the few general facts connected with the decompositions to which they are liable from the reaction of their constituent principles, either at high or at low temperatures.

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#### CHAP. I.—OF THE FORMATION OF ANIMAL SUBSTANCES.

ANIMAL substances are distinguished by nearly the same general chemical characters as vegetable products. They are formed of a few ultimate principles, the diversities in their properties arising chiefly from the proportions and modes in which these are combined. From this peculiarity of constitution, they have the same susceptibility of decomposition as vegetable substances have, the balance of affinities among their elements being easily subverted, and new combinations established. Hence, too, their analysis is always of the complicated kind, their principles not being disengaged insulated, but in new states of chemical union.

With regard to the distinction between the vegetable and animal compounds, the latter are more liable to decomposition from the reaction of their elements. The



kind of spontaneous decomposition, too, which they suffer, is different. They are scarcely susceptible of the vinous fermentation; they seldom even pass into the acetous, but undergo putrefaction, a process in which the principal products are ammonia, and various gases, having an offensive odour, by the evolution of which the whole nearly of the original matter is dissipated. In their decomposition by heat, ammonia is a principal product; prussic acid is usually formed, elastic fluids are disengaged similar in chemical composition to those evolved in putrefaction, and the residual charcoal affords phosphoric salts.

These differences arise from the peculiarities in the composition of animal matter. Being more complicated than that of vegetable matter, or formed from the union of a greater number of elements, the affinities these reciprocally exert are more nicely adjusted, and are hence more easily subverted. In animal substances are contained not only carbon, hydrogen, and oxygen, the usual constituent principles of vegetable matter, but nitrogen in considerable quantity, and sulphur and phosphorus in smaller proportions. From the nitrogen they contain, is derived the abundant formation of ammonia which attends their decomposition, and its predominance in their composition is shewn by its evolution when they are acted on by nitric acid. The presence of sulphur and phosphorus is discovered, by the disengagement of sulphuretted and phosphuretted hydrogen gases during the putrefaction, or decomposition by heat of animal matter: the acids formed by their oxygenation are also found in the residual charcoal, combined usually with soda and lime. Carbon is contained in animal substances, in a proportion inferior to that in which it enters into the composition of vegetable products; hence they give less carbonic oxide and car-



bonic acid in the decomposition; on the contrary, hydrogen appears to be predominant, from the large quantity of empyreumatic oil which they usually afford. Gay-Lussac and Thenard, from an analysis of a number of animal principles, by the oxygenating agency of peroxide of copper, have shown, that in several of the most important of these, the quantity of hydrogen is such as is equivalent to convert all the oxygen into water, and likewise all the nitrogen into ammonia.

The animal products are ultimately derived from changes produced in the composition of vegetable matter, all animals living directly, or indirectly, on vegetable food; and even the present imperfect state of chemistry enables us to trace, in part, their formation,—the conveyance of their elements, and the processes by which these are brought into the combinations, whence the varieties of animal matter are formed. Vegetable matter is composed chiefly of carbon, hydrogen, and oxygen; and can, therefore, furnish these elements. From the same source, or from the water with which the animal is supplied, may be derived the lime and iron, contained in small quantity in the animal products; at least the only difficulty, with regard to these, is in the case of those animals by whom a large quantity of lime is secreted in the formation of their shells. There is a greater difficulty with regard to the source of the nitrogen, which is so abundant in animal matter; for although it is contained in some vegetable substances, it is not a common principle, and is usually in small proportion; and it does not appear that any portion of it is conveyed, as was once supposed, into the blood, by respiration, from the atmospheric air \*. Phosphorus is another

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\* Though nitrogen is not, properly speaking, consumed in the chemical process of respiration, yet Dr Murray has pointed out a



principle, the origin of which is not obvious; it is always contained in animal substances, and even a considerable portion of it, in the state of phosphoric acid, is discharged as excrementitious, yet is rarely found in vegetable matter. Still it has been shewn, that in those vegetables which are most nutritious, as in wheat, phosphorus is a constituent principle, wheat-flour, for example, yielding by incineration phosphate of lime; and it

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method by which he conceived that nitrogen may be conveyed into the blood from the lungs. The residual air, as he remarked, which occupies the air cells after expiration, is principally nitrogen. An air of this kind constantly remaining in the bronchiæ, and being applied to the moist surface of the membrane forming the minute blood-vessels, a portion of it, condensed by the humidity of that membrane, may permeate it, and be absorbed into the mass of blood. This effect may be altogether unconnected with the chemical changes of the air in respiration, and may proceed so slowly as not to be discoverable with precision by any change in the inspired air, while, at the same time, acting constantly, it may be sufficient to afford the whole of this element, which is necessary to the formation of animal matter. In most experiments on the subject, a small diminution of volume in the air respired has accordingly been noticed, which has generally been ascribed to accidental causes, but may arise from this gradual absorption of nitrogen. Additional probability is given to the hypothesis suggested by Dr Murray, by the late able researches of Dr Edwards, who has clearly proved, that the quantity of nitrogen expired by animals is frequently perceptibly less than what is drawn in by inspiration. It may be remarked, that the greater number of experiments on this question have been made on the respiration of man, who, receiving a considerable quantity of nitrogen in animal food, requires little or no additional portion; they ought rather to be made on the larger herbivorous animals, which receive nitrogen from scarcely any known source, and yet expend a large quantity of it in the formation of animal products. ED.



is only in those animals who feed, in part at least, on animal matter, that the urine holds phosphoric salts dissolved. These facts lend probability to the supposition, that it is conveyed by the food. The principles conveyed by the food, from which animal nutrition is ultimately derived, are brought into those combinations productive of the several varieties of animal matter, by the united processes of digestion, respiration, and secretion; and the operation of these, so far as it can be done, it is satisfactory to trace.

In digestion, the food is submitted to the action of the gastric juice, or liquor secreted by the glands of the stomach, at a temperature, in the more perfect animals, above  $90^{\circ}$ , and to the pressure, more or less forcible, arising from the contraction of the stomach itself. It is thus resolved into a soft pulpy mass, in which the previous texture or nature of the aliment can scarcely be distinguished. By facts to be afterwards stated under the chemical history of the gastric fluid, it is proved, that it is principally by the solvent power which it exerts, that this digestion of the food is effected. The nature of the change itself is not very well ascertained; but the food does not seem to be resolved into its ultimate elements; its soluble parts rather appear to be extracted without decomposition, and brought into intimate mixture, while there is also a partial animalization, by the intermixture of the saliva and gastric fluids. The digested food conveyed into the intestinal canal probably continues to suffer further changes, promoted by the temperature and alternating pressure; and more directly produced by the action of the pancreatic juice and the bile; after the intermixture of the latter fluid, traces of the chyle are observed, and this milky fluid, in the progress of the food through the intestinal canal, is absorbed by the lacteals, and conveyed into the mass of blood. Chylification, therefore, is the last stage in the process of digestion; the



precise nature of the changes which constitute it are not ascertained, but, from the opaque milky appearance of chyle, it is obvious that it is not a perfect solution; the more soluble principles of the food are, no doubt, dissolved in it; others less soluble, but probably nutritious, appear to be suspended in it; and the whole is so far animalized as to contain a product approaching to one of the most important principles of animal matter, albumen, capable of being discovered in it by coagulation by heat.

There is a chemical change constantly produced in the blood by the process of Respiration, probably connected with the process of animalization. While it circulates through the lungs it is exposed, in the minute blood-vessels, to the action of the atmospheric air, alternately taken in and thrown out in breathing. A portion of carbonic acid is formed, and discharged from the lungs, the quantity of oxygen necessary to form this being furnished by the atmospheric air inspired. The blood loses, therefore, a portion of carbon, with which this oxygen combines; and as this process is constantly carried on, it must be connected with the changes which the blood suffers in the system,—in other words, with the formation of the animal products. It is not improbable that a portion at least of this carbon is derived from the imperfectly assimilated chyle; and as animal matter contains less carbon than vegetable matter, it probably remains redundant in the blood, after the formation of the principles of that fluid from the chyle, or of the other animal products in the course of the circulation; a principal office, therefore, of respiration, is probably to remove this excess of carbon.

Lastly, By Secretion the animal fluids and solids are formed. Either in the extreme blood-vessels, or in the minute and convoluted vessels which constitute the glands,



the blood suffers changes of composition, whence the production of the several varieties of animal matter. The nature of the process of secretion, by which this is accomplished, is extremely obscure; but it is evident, that however the actions of the vessels, whence the changes arise, may be dependent on their vitality, the changes themselves are strictly chemical. And it may perhaps be proposed, as no improbable hypothesis of the nature of secretion, that the cause productive of the new combinations to which it gives rise, is chiefly the approximation of the elements of the blood, by the contraction of the vessels through which it is transmitted. It is urged, by the contractile force of the heart and arterial system, through vessels extremely minute, and even the diameters of these vessels are alternately diminished and enlarged by their alternate contraction and relaxation. By this, an approximation and change in the relative positions of the particles which compose the principles of the blood must be produced. There can be no doubt, that the force of attraction between the minute particles of matter is materially modified by the distances at which they are placed; by such a cause, therefore, changes in the exertion of attraction to the principles of the blood may be produced, and be productive of all the combinations to which secretion gives rise.

By secretion a variety of products are formed,—as bile, milk, &c.; and by an analogous process, carried on without the intervention of glands, in the extreme blood-vessels, are probably formed the principles of the blood itself, and of the animal solids. The process of animalization is thus completed, and, from the progressive operation of these general processes, Digestion, Respiration, and Secretion, the formation of animal matter is traced.



## CHAP. II.—OF ANIMAL PRODUCTS.

THE different varieties of animal matter may probably, like vegetable substances, be comprised under a certain number of well-defined species. This, however, is as yet imperfectly attained; we therefore consider merely the principal animal fluids and solids, introducing under their history those specific distinctions which can be established, and the notice of those principles which are characterised by these distinctions. The blood may first be considered as the source of the others; and its history is important, as it contains those proximate principles of which the other varieties of animal matter are principally formed.

SECT. I.—*Of the Blood.*

THE blood, or common fluid which circulates in the vessels of the animal system, differs in the different tribes of animals. It is from its properties in the more perfect, or warm-blooded animals as they are named, that its chemical history is drawn.

While in the vessels of the animal system, it appears to be homogeneous. The microscope discovers it, however, to consist of globules diffused through a liquid; and these are so minute, that they are not capable of being separated by any mechanical operation. After the blood has been drawn, however, for a short time, it coagulates and separates into two parts, one solid and firm, of a red colour, the other liquid, of a slight yellowish tinge. The former is named the Crassamentum, the latter the Serum. By a farther simple analysis, that of washing with water, the crassamentum is resolved into two parts, a firm white



elastic substance, insoluble in water, which has been named Gluten or Fibrin, and the Colouring Matter of the blood, which is carried off in a state of suspension or solution. This coagulation affords the most simple and direct mode of discovering the immediate constituent principles of the blood.

The liquid portion, or Serum, is of a pale yellowish colour, somewhat tenacious, and has a saline taste. It is miscible with water; a little free soda exists in it; whence it changes the blue colour of violet to a green.

It coagulates from the application of heat, raised to  $160^{\circ}$ , forming a mass more or less firm, but tremulous, with a portion of liquid diffused through it, which contains a little muriate of soda. It is also coagulated by the action of a number of the acids, by salts with an excess of acid, by alcohol, and by some metallic oxides. The substance which coagulates exists in many of the animal products besides the blood. It is named ALBUMEN, and is the first immediate principle existing in this fluid, the properties of which are to be pointed out: the white of an egg affords an instance of it easily procured and examined. Liquid Albumen is a thick fluid, insipid, alkaline from the presence of a little free soda, soluble in cold water, but is separated from it by coagulation at temperatures above  $160^{\circ}$ , and also by the action of those re-agents which separate it from the serum. After coagulation, it is insoluble in water. This character of coagulation by heat takes place even in very dilute solutions of this principle, and is distinctive of it. It is also coagulated by alcohol and by acids, which is supposed by Berzelius to be from the albumen forming with an excess of acid an insoluble compound. The sulphuric acid, when concentrated, dissolves albumen, and forms a dark solution; according to Dr Hope, this solution, when heat is cautiously



applied to it, becomes of a rich red colour. Nitric acid, by long maceration, converts albumen into a species of gelatin. When strongly heated albumen affords the usual products of the decomposition of animal matter; according to Dr Prout, it consists of carbon, 50, oxygen, 26.67, nitrogen, 16.55, and hydrogen, 7.78; or of 15 atoms of the first, 6 atoms of the second, 2 of the third, and 14 of the fourth ingredient, which would give an equivalent of 180. Sulphur appears to be often present in it: hence, when it is triturated with nitrate of silver, the sulphuret of the metal is formed.

The chemical test by which the presence of albumen can be recognised with the greatest delicacy and accuracy is corrosive sublimate, a few drops of its solution detecting, by the milkiness it produces, albumen dissolved in 2000 parts of water. Goulard's Extract, nitrate of silver, and tannin precipitate it; but they are of less utility as tests, as they act on other principles of animal matter.

When a fluid containing albumen is placed in a galvanic circuit, soda appears at the negative pole, and albumen coagulates rapidly at the positive. Mr Brande, by whom this was first noticed, and who showed it to be a very delicate test of albumen, attributes the coagulation to the separation of the soda, which, it is conceived, gives solubility to albumen. Lassaigne ascribes it to the decomposition of muriate of soda, the acid of which, collecting at the positive pole, coagulates the albumen.

The cause of the coagulation of albumen is obscure. It has been supposed by Dr Thomson, that the solubility of this principle arises from the presence of free soda; and hence, whenever this is neutralized by an acid, or transferred to the watery part by the application of heat, the albumen being naturally insoluble, is separated; this opinion is improbable, and, besides, the objection applies to it, that the quantity of alkali in albuminous fluids is ex-



tremely small. It might be supposed to be owing to its slight affinity to water, whence, when separated, it becomes insoluble; but it is found, that by exposing albumen in thin layers to the air, it may be dried, and still retains its solubility in water. Albumen in coagulating does not appear to undergo any change of composition; it is much less liable however to putrefy than when fluid. It is dissolved by the fixed alkalis, giving out ammonia. In this coagulated state it very much resembles fibrin.

Albumen exists in many of the soft solids. Mr Hatchet's experiments prove that it forms the base of cartilage, shell, horn and hair, and exists in the composition of membrane, muscular fibre, and bone.

The liquid diffused through the coagulum of the serum, when pressed out from the albumen, has been named the Serosity. If it be made to boil gently, it becomes gelatinous on cooling. This being the distinguishing property of a principle existing in various animal solids, and denominated from it Gelatin, it has been inferred, that it is one of the constituents of the blood; an opinion disproved, however, by Dr Bostock, who has shewn the appearance to be owing to a little of the albumen of the serum having dissolved in the liquid after its coagulation by heat. There is, besides the albumen, a small quantity of an uncoagulable matter, which differs both from albumen and gelatin; Mr Brande supposes a large proportion of alkali to exist in the serosity.

The serum of human blood contains in 1000 parts, according to Berzelius, water, 905, albumen, 80, muriates of potash and soda, 6, lactate of soda and animal matter, answering to the *muco-extractive* matter of Dr Marcet, 4, soda, phosphate of soda and a little animal matter, 4.1. The lactate of soda may be regarded as an impure acetate.

The Crassamentum of the blood is of a soft consistence,



and a dark-red colour, which becomes florid at the surface, from exposure to atmospheric air or oxygen gas, while it is rendered of a darker hue by other gases. Though apparently homogeneous, it is resolved, by the mere affusion of water continued sufficiently long, into two parts; the Colouring matter is carried off in the water, and there remains a white fibrous substance denominated Fibrin.

The colouring matter may be obtained by evaporation of the water, but is then mixed with serum. The method of Berzelius is to cut the crassamentum into thin pieces and dry it on blotting paper, then to agitate it with water, and evaporate the solution. Even as thus procured it is not pure; and it has been found by Engelhart to be a preferable method to dilute the serum with a large portion of water, and apply heat to it, when the colouring matter falls down in brown flocculi. It is somewhat changed, however, by this process, so as to be insoluble in water, while, in its usual state, it is soluble in that fluid. When dried, it is a tough hard mass, with a resinous fracture, and a very dark-red colour. The colouring matter appears, from microscopical observations, to be in the form of minute particles, from 1-6000th to 1-4000th of an inch in diameter: these are globular in the blood of warm-blooded animals, but are said to be elliptical in that of birds, and cold-blooded animals. These consist, however, of two substances, colourless globules, insoluble in water, which float on the surface, and the colouring matter, which is dissolved by water. The solution is of a bright red colour; when heated to about 170° it becomes brown, and a flocculent precipitate subsides, from which the liquor above may be obtained colourless by filtration. Acids also dissolve the colouring matter more or less completely;—muriatic acid renders one part insoluble, and dis-



solves another, forming a dark crimson solution ; sulphuric acid diluted with eight or ten parts of water, with the aid of heat, forms a purple solution ; nitric acid changes the colour to a brown ; the acetic, and several of the vegetable acids, dissolve a considerable portion of it. The alkalis, both pure and in the state of carbonate, form deep red-coloured solutions, which are permanent. This colouring matter of blood farther exerts affinities to argil, oxide of tin, and oxide of mercury, so as to be abstracted by them from solutions in which it exists ; and there is reason to believe, that by the intermedium of mordants it may be made to form a permanent red dye. In the state in which it exists in the blood, it is peculiarly acted on by the gases, oxygen communicating to it a florid red colour, hydrogen, carbonic acid, and other gases, giving it a dark purple hue.

There is much uncertainty as to the cause of the colour of the red globules. The common opinion has been, that it is derived from oxide of iron, that metal being obtained from the crassamentum by incineration. This oxide of iron was inferred by Fourcroy and Vauquelin to exist in the blood in the state of sub-phosphate. They obtained from evaporation of the solution of colouring matter, phosphoric acid and oxide of iron. Sub-phosphate of iron they stated to be of a brownish-red colour, and to be soluble in alkalis : hence it would be retained in solution by the soda of the blood. In confirmation of this they affirmed, that sub-phosphate of iron is soluble in the serum of the blood, or in the white of an egg, which is albumen nearly pure, and that by the addition of a little alkali it assumes a lively red colour. The colouring matter of the crassamentum, therefore, they regarded as albumen with sub-phosphate of iron.

Some of these results, however, always appeared doubt-



ful, and from the later experiments of Berzelius, appear to be incorrect. The sub-phosphate of iron, he shewed, is not dissolved by serum; and though rendered soluble by an excess of phosphoric acid, gives only a brown tint, very different from that of blood. He found, however, that oxide of iron, to the amount of half a *per cent.*, is obtained by incineration of the colouring matter, while none exists in albumen and fibrin. Mr Brande has stated results contrary to these; but it would appear that he had not separated the colouring matter completely from the two latter principles, which, when pure, it has been proved by Engelhart, contain no iron. A singular circumstance is, that though iron is thus obtained by incineration, a number of chemists have been unable to detect any trace of it in the blood, or in solutions formed from it, even by very delicate liquid tests. This has been explained by M. Rose, who has shown, that iron is not precipitated by these tests from fluids containing albumen, or other soluble animal principles. Engelhart has accordingly shown, that if chlorine be transmitted through a solution of the red globules, by which the colour is destroyed, and white flocculi of animal matter precipitated, the peroxide of iron can then be detected by its tests in the clear liquid. These different facts prove some connection between the colour and oxide of iron; but it is not yet ascertained what this connection is, in what state this oxide exists, or how it gives rise to so deep and uniform a colour; nor is it obvious how carburetted hydrogen should produce so great a change on it.

The Fibrin, which is the other constituent part of the crassamentum, remains when the colouring matter has been removed by the affusion of water; it is also obtained by agitating the mass of blood itself with a rod, the serum and colouring matter being mixed by the agitation,



while the fibrin adheres to the rod. It is sometimes found concreted in the large blood-vessels after death, forming what have been named Polypi; and in inflammatory diseases, it gives rise to the appearance named the *buffy coat*. The same principle exists in other animal products; it is in particular the basis of the Flesh, or Muscular Fibre.

Fibrin, as it exists in the blood, is in the state, according to Mr Bauer, of very minute white globules. When obtained in the manner that has been mentioned, it is a solid elastic substance, of a fibrous texture, of a white colour, inodorous and tasteless; it shrinks when dried and exposed to heat; it is insoluble in water, except at a high temperature, obtained by applying heat under compression. In a humid state it is liable to spontaneous decomposition, softening, and at length becoming putrid. Alcohol and ether convert it into a kind of fatty matter. It is dissolved by the alkalis, but is at the same time altered. The acids act on it. When digested with an equal weight of sulphuric acid, according to Braconnot, it is dissolved without any change in it, or in the acid; this solution being diluted with water, boiled for nine hours, and the acid separated by chalk, the extract acquires a taste of osmazome; and by the action of alcohol, a peculiar white matter is separated, which Braconnot has named Leucine. Muriatic acid hardens fibrin instead of dissolving it, and the strong acid decomposes it. Nitric acid disengages from it nitrogen gas in large quantity, and nearly pure, and forms other products, the most remarkable of which is a peculiar yellow, bitter matter,—what has been named Yellow Acid, considered by Berzelius as composed of altered fibrin, with nitric and malic acids. Acetic acid dissolves fibrin, but so far changes its composition, that when it is precipitated by the alkalis, it no longer has its origi-



nal properties. According to Gay-Lussac and Thenard, fibrin is composed of carbon 53.36, hydrogen 7.021, oxygen 19.685, and nitrogen 19.934; hence it is inferred to consist of eighteen atoms of carbon, 108, five of oxygen, 40, fourteen of hydrogen, 14, and three of nitrogen, 42, = 204.

After this enumeration of the constituent proximate principles of the blood, the properties of the entire compound itself, which in a great measure result from these, will be better understood. When newly drawn, it appears homogeneous; it is soluble in water. As has been already mentioned, it soon suffers spontaneous coagulation, separating into the Serum and Crassamentum. This coagulation is accelerated by heat, and is retarded by cold, as has been shown by Dr Scudamore. It is also somewhat retarded by excluding the air from it, though it takes place *in vacuo*, and, it has been affirmed, even more quickly than when exposed to the atmosphere. It happens when the blood is rapidly agitated or stirred, equally as when it is at rest. It may be prevented, however, by diluting the blood copiously with water, or by adding to it some saline solutions. The blood of persons who have died a sudden death, by violent passions, or some kinds of poison, does not coagulate spontaneously. The same fact has been stated with regard to animals killed by electricity and lightning; but this has been contradicted by Dr Scudamore. It appears, that in the living body, blood, though its communication with the rest of the circulating fluid is cut off, as by ligatures, coagulates very slowly and imperfectly. It has been affirmed by Brande, that in the coagulation of blood carbonic acid gas is given out; but it would appear, from the experiments of others, that the statement is incorrect, and that the gas must probably have been previously ab-



sorbed by the blood from the atmosphere. It has been found by Dr Gordon and Dr Scudamore, that caloric is evolved in the coagulation of blood, a result conformable with what is generally observed in the congelation of fluids. The cause of the coagulation of the blood is as yet obscure. From the facts that have been mentioned, it obviously depends neither upon rest, nor exposure to the air, nor reduced temperature, the causes generally assigned for it. The opinion now commonly received is, that the fluidity of the blood depends immediately on the agency of the vital principle; and when this vitality is destroyed, the contractile power of the fibrin probably gives rise to the coagulation. The appearance called the Buffy Coat, observable in blood drawn in inflammatory diseases, is owing apparently to the coagulation being slow, so that the red globules have time to subside, leaving the upper surface of the same pale colour as the crassamentum exhibits when it has been washed with water.

The blood is immediately decomposed by acids, which render its colour dark, and produce coagulation. The metallic salts in general decompose and coagulate it. It soon passes into putrefaction; but if the watery part be dissipated by evaporation, and the solid matter be rendered perfectly dry, this change takes place very slowly. Decomposed by heat, it affords all the products of animal matter; a large quantity of ammonia is produced; the elastic fluids disengaged are extremely offensive, the charcoal which remains is brilliant, and of difficult incineration; when burnt, it affords a portion of oxide of iron, with various saline and earthy substances, principally phosphate and carbonate of lime.

IN concluding the history of the blood, it is necessary



to remark, that there is an important difference in it, as it exists in the arteries and in the veins of an animal ; and this difference, from the known operation of the cause by which it is produced, must depend on a chemical change. The venous blood returned from the extreme vessels to the heart, is brought by the pulmonary arteries to the lungs, through which it circulates, exposed to the air received in respiration, under a very extensive surface, and with the interposition of a very thin membrane, which appears not to prevent the reciprocal action of the air and blood. Part of the oxygen of the inspired air is consumed, and a portion of carbonic acid gas is formed, which is expired with the residual air ; the blood at the same time loses its dark purple colour, and acquires a vivid vermilion hue ; it is returned to the left side of the heart, is conveyed by the arteries to the different parts of the system, and again converted to the venous state. These reciprocal changes are obviously connected with changes of composition, and are hence subjects of chemical investigation.

Many experiments have been made to determine the relation between the consumption of oxygen by respiration and the formation of carbonic acid, and the extent of these changes. These have presented very discordant results. It had often been supposed that there is an excess of oxygen consumed, above that which is necessary to the formation of the carbonic acid gas which is produced ; but the experiments of Allen and Pepys have proved that this is not the case, but that the one is equivalent to the other. In the lower animals, however, it has been shown by Dulong, that this equality does not in all cases exist, some animals consuming more oxygen than they evolve carbonic acid. In man the absolute quantities of the two gases vary : in respiration quickly performed, the



quantity of carbonic acid gas produced seems to amount to 32 cubic inches in a minute; in respiration as nearly natural as possible, it appears, from the experiments of Allen and Pepys, to amount to 26.6 cubic inches in a minute; and as oxygen gas occupies the same space, when converted into carbonic acid gas, which it does in its pure form, this of course gives the quantity of oxygen consumed in the same time. The changes, however, are considerably influenced by circumstances. Thus the consumption of oxygen is greater at a low than at a high temperature; during digestion, its consumption is also increased, as it is by muscular exertion. And the experiments of Dr Prout have shewn, that other circumstances, such as the time of the day, exercise moderate or violent, food, spirituous liquors, the passions, affect the results. In the morning and early part of the day, the consumption of oxygen and corresponding formation of carbonic acid are greater than in the afternoon and evening,—moderate exercise at first increases the production of carbonic acid, but soon ceases to have that effect; fatigue and violent exercise diminish it,—spirituous liquors diminish it, as do the depressing passions,—and the effects of all these seem in some measure unconnected with their operation on the circulation, or are not proportional to it. Experiments attended with similar results have been stated by Dr Fyfe.

The phenomena of respiration are nearly the same in all animals: they all require oxygen, and expire carbonic acid, though the quantities are different in different orders. In warm blooded animals the changes proceed to the greatest extent, and the presence of oxygen is most indispensable; and amongst these, this is in a great measure in proportion to the size of their lungs. Some interesting facts have been stated by Mr Edmonstone, re-



lative to the state of the blood in various aquatic animals, as seals, whales, and in sea birds, which have the power of suspending respiration for an interval that would be fatal to other warm blooded animals. He has shown that the blood in them is in a sub-arterial state, or is less oxygenated than in warm blooded animals, which have not this power. In the *amphibia* the supply of air is still less necessary, though they require a supply of it in a certain degree, and produce in it the usual changes. Fishes, it has been shown by Humboldt and Provençal, consume oxygen and produce carbonic acid, a function performed also, though languidly, by worms and insects.

It is a just observation by Berzelius, that the quantity of carbonic acid gas which has been stated to be produced in respiration is such, as to involve a difficulty with regard to the quantity of carbon which must be inferred to be abstracted from the system. Taking the estimate of Allen and Pepys, that 26.6 cubic inches of this gas are expired in a minute, this implies a consumption of about 11 ounces of carbon in 24 hours, a quantity certainly exceeding the quantity contained in the average proportion of food taken in that time. The estimate, therefore, in this, as well as in other experiments, is undoubtedly too high; arising probably from the difficulty of imitating natural respiration, and the tendency there is in all such experiments, to relieve the uneasiness which attention to the act of respiration causes, by making the inspirations either frequent, or if slow, to make them full: whence both the formation of carbonic acid may be rendered greater, and the proportion, when the estimate is extended to 24 hours, will be augmented.

From experiments by different chemists, there appeared to be a consumption of nitrogen in respiration. Messrs Allen and Pepys found that this is not the case; the ap-



parent loss of nitrogen being owing to respiration becoming more laborious as the experiment goes on, in the manner in which it is usually performed, so that at the close the full proportion of air is not thrown from the lungs. Dr Edwards, however, has lately found, that in animals the quantity of nitrogen expired is sometimes less than what is drawn in, and sometimes, on the contrary, it is greater; and that these changes are connected with the season of the year. In winter, it appears, that nitrogen is consumed or lost, while in summer more is given out by respiration than what exists in the air inspired. In these cases, it may happen, either that two processes go on at different times, one of absorbing nitrogen by the surface of the lungs, and another of exhaling it by the same medium, or both processes may go on together: some experiments of Allen and Pepys are in favour of the latter opinion. A portion of watery vapour is given out in respiration, equal to between two and three grains in a minute, and obviously derived from evaporation from the humid surface of the lungs.

Different views have been presented of the manner in which the chemical changes that occur in respiration are produced. Crawford, who gave the first precise explanation, supposed, that in the course of the general circulation, and more especially in the extreme vessels, the arterial blood receives a supply of what he termed hydrocarbon, or the compound of carbon and hydrogen, which in its elastic form constitutes carburetted hydrogen: by receiving this, it becomes venous blood, and during the circulation of this blood through the lungs, the hydrocarbon permeates the thin membrane in which the blood is inclosed, and combines in its nascent state with the oxygen of the inspired air, forming carbonic acid gas and watery vapour, which are expired. And the blood, losing



this hydro-carbon, resumes its arterial state. A different view was suggested by Hassenfratz and Lagrange,—that the oxygen which disappears in respiration may be absorbed in the blood; may, in the course of the circulation, combine with carbon to form carbonic acid, and this acid, conveyed by the venous blood, may be discharged in the lungs. Both hypotheses are defective. There is no proof in that advanced by Crawford, of carbon and hydrogen being communicated to the blood in the extreme vessels, or of the existence of such a compound as carburetted hydrogen in venous blood; and the experiments of Allen and Pepys farther prove, that the oxygen of the air is replaced by an equal quantity of carbonic acid, so that it cannot have combined with any hydrogen. There is an equal deficiency of proof in the opposite hypothesis, that oxygen is absorbed, or exists in arterial blood in a state of loose combination, or that carbonic acid is present in venous blood in a similar state: the last supposition seems even to be precluded by the fact, that when blood has absorbed carbonic acid, it is not rendered florid by exposure to oxygen. These supposed changes are also unconnected with any of the purposes to which the blood is subservient, and are analogous to none of the chemical changes which take place in the animal system.

An opposite view, therefore, ought to be taken of these changes. The conversion of arterial into venous blood ought to be considered as the result of the chemical processes of the animal economy carried on in the extreme vessels; and this conversion, as well as that of venous into arterial blood, must be regarded as arising from changes in the ultimate composition of the known proximate principles of the blood, not from the alternate communication and abstraction of a principle which it holds dissolved in a state of loose combination. Under this view of the sub-



ject, I have given the following explanation of these phenomena. The blood is the source whence the products of the animal system are formed. Its expenditure is supplied by the chyle, a fluid less completely animalized than the blood itself. That a redundancy of carbon is communicated by this fluid to the animal frame is proved by the very fact, that in respiration a quantity of carbon is removed; the redundancy of this principle will necessarily appear first in the extreme vessels in which the elements of the blood are combined, and modified, so as form the animal solids and fluids; and this increased proportion of carbon appears to constitute the *conversion of arterial into venous blood*. In respiration, the oxygen of the inspired air acting on the extensive surface of the blood circulating through the lungs will abstract a portion of carbon, forming carbonic acid: and this gives rise to the *conversion to the arterial state*. The accumulation of carbon is thus prevented, and the due proportion of the elements of the blood preserved.

From the chemical changes which occur in respiration, has been derived the explanation of that uniform temperature which animals preserve, in general superior to that of the medium in which they live. Dr Crawford first explained this doctrine with precision, and supported it by experiments. He had shewn, that in general, when inflammable bodies combine with oxygen gas, a diminution of capacity takes place, whence there must be an evolution of caloric; and more particularly that, in the combustion of charcoal, when carbonic acid is formed from the combination of oxygen with carbon, a large quantity of caloric is rendered sensible. It is evident, that since in respiration a similar consumption of oxygen and production of carbonic acid take place, there must be a similar evolution of caloric. He farther found, by experiment, that



the capacity of the blood changes when it passes from arterial to venous, and of course from venous to arterial; that of arterial being larger than that of venous blood, in the proportion of 1.030 to 0.892. On these facts he founded his admirable theory of Animal Heat. In respiration, a quantity of oxygen is combined with carbon, and carbonic acid is formed. Caloric must be evolved in consequence of this combination. But the blood is at the same time changed from venous to arterial, and by this change acquires a greater capacity for caloric. It therefore takes up the caloric which has been extricated by the combination of the oxygen with the carbon; so that any rise of temperature in the lungs which would be incompatible with life is prevented. The arterial blood, in its circulation, passes to the venous state. In this conversion, its capacity for caloric is diminished, as much as it had been before increased in the lungs; the quantity, therefore, which had been absorbed, is given out; and this slow and constant evolution of heat in the extreme vessels over the whole body is the source of its uniform temperature.

Besides the experiments from which this theory was directly deduced, it has been strengthened by others, in which the quantity of caloric rendered sensible by an animal was measured. Crawford, and Lavoisier and Laplace, found, that when an animal was confined in a vessel, contrived so as to measure the quantity of heat which it gave to the surrounding medium in a certain time, and the quantity of oxygen consumed by the animal, this quantity of caloric corresponded nearly to the quantity evolved from the combustion of carbonaceous matter, such as wax or oil, in the same quantity of oxygen. It has been remarked too, with regard to the different classes of animals, that the temperature of the body above that of the surrounding medium is higher the larger the lungs are,



and the greater the quantity of oxygen they consume ; a fact which shews a very strict connection between the chemical changes in respiration, and the source of animal heat. Dr Edwards has also shewn that very young animals, which have not the power of sustaining their own temperature, may be excluded from oxygen altogether for some time without suffering any injury ; while to others, which, however young, are able to keep up the animal temperatures, respiration is as indispensable as to the adult animals.

Objections have been raised to this theory, from experiments by Mr Brodie, in which it appeared, that when artificial respiration was kept up in an animal newly killed, so that the circulation of the blood through the lungs went on, and even the usual changes in its appearance, and the corresponding changes in the air were produced, still the temperature of the animal fell. He considered this result as subversive of the theory of Crawford, and as proving that animal heat, instead of depending on the chemical changes which occur in respiration, is rather under the influence of the brain and nervous system.

There can be no doubt that the animal temperature is to a considerable extent under the influence of nervous energy. But, on the other hand, in whatever way the fact is to be explained, it is uniformly found, that when oxygen is converted into carbonic acid, a large quantity of heat is evolved, and no reason can be pointed out why this should not happen in respiration as in other instances. Moreover, there is no proof, that in Mr Brodie's experiments the blood suffered the changes which it undergoes in the extreme vessels during life ; for it is possible that the blood in the course of circulation may lose its florid colour, and yet, under that state of the system in which nearly all the functions are suspended, may not become,



properly speaking, venous blood, or have its capacity so diminished as to prove a source of heat: and this blood may, for a long period, afford carbon to form carbonic acid when acted on by the air in the lungs, and from this change may suffer augmentation of capacity, so that its temperature shall not rise,—these changes arising from the mere chemical action of the air on the blood, unconnected with the exercise of any vital function in the extreme vessels. Caloric, therefore, may be communicated to the blood in the lungs, and yet neither raise its temperature, nor be evolved in the extreme vessels under the circumstances under which these experiments were performed \*. Even these suppositions are not requisite, as Mr Brodie's ex-

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\* Dr Murray has remarked in his *System of Chemistry*, (vol. iv. p. 489,) that Mr Brodie's experiments are in fact favourable to the theory of animal heat being owing to the chemical changes produced in the blood by the lungs. In these experiments, while an animal newly killed was subjected to the influence of artificial respiration, another animal of the same species and size, killed at the same time, was placed under a similar vessel, but without artificial respiration, so that the fall of its temperature might be compared with that of the former. The difference was in general inconsiderable. In the first experiment, for example, the temperature of the animal subjected to artificial respiration had fallen in 30 minutes from  $97^{\circ}$  to  $90^{\circ}$ ; that of the other in the same time from  $97^{\circ}$  to  $91^{\circ}$ ; and in other experiments the differences were the same, or even less. Now, the circumstance appears to have been overlooked, that in the former animal, during the whole period, air was forced into the lungs, and withdrawn at the rate, as is mentioned, of about 50 inflations of the lungs in a minute; and to this air thus constantly renewed, and in the interval exposed to the cooling agency of a glass vessel of the capacity of 500 cubic inches, the bulk of the animal itself being 50 cubic inches, the whole mass of blood circulating through the lungs was exposed, by which it must necessarily have been constantly cooled. Yet, not-



periments have been contradicted by those of other physiologists. Other objections have been stated to Crawford's theory, on the grounds, first, that Dr J. Davy did not find the capacities of venous and arterial blood to differ in any great degree; and, secondly, that, as has been stated before, the results of Berard and Delaroche, relative to the capacities of oxygen and carbon, are opposed to those of Crawford's. As has been already remarked, it will require very careful and repeated experiments before the contradictory statements with respect to the capacities of bodies for heat be explained and reconciled. Even if these objections be admitted as decisive against the theory of Crawford, the opinion, that respiration is in a great measure the source of animal heat, may still be maintained, as resting directly on the established fact, that when oxygen gas is converted into carbonic acid, heat is given out. On the whole, it may be concluded that animal heat is principally derived from the changes produced in the blood in the processes of secretion and nutrition, and the reverse change which it suffers in the lungs; in the former changes the other elements of the blood being chiefly consumed, and carbon left redundant; in the latter, this carbon being removed by union with oxygen, and conversion into carbonic acid, an evolution of heat attending the combination, which being absorbed by the blood, is by its circulation distributed through the system. And these processes, we have rea-

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withstanding these sources of the constant abstraction of heat, the fall of temperature at the end of 30 minutes was not greater than one degree more than where they were not present,—a sufficient proof, remarks Dr Murray, that heat must have been generated, and to a considerable amount, solely by the chemical changes, imperfect as they probably were. Ed.



son to believe, are, to a considerable extent, affected by the influence of nervous energy.

Transpiration is a function analogous to respiration, and gives rise to similar changes, though to a much less extent. Carbonic acid gas is exhaled from the skin with watery vapour, and oxygen is consumed, or rather, perhaps, the oxygen of the air acts on the transpired matter, and forms carbonic acid. A small portion of acid, apparently acetic, appears to be secreted by the cutaneous vessels, with a little muriate of soda.

SECT. II.—*Chyle, Milk, Sugar of Milk, and Saccho-lactic Acid; Eggs.*

CHYLE is the fluid taken up by the lacteals from the food which has been digested in the stomach, and conveyed into the intestinal canal. It is conveyed by the thoracic duct into the mass of blood, and is obviously the source whence the expenditure of matter in the formation of the animal products is supplied.

The chyle varies in its appearance, according as it has been collected at a greater or less interval from the time when the animal had received food. It is a white opaque fluid like milk; its taste is sweetish, and slightly saline; it slowly changes the colour of violet to a green. On exposure for a short time to the air, it becomes gelatinous, and after some hours separates into a firm coagulum, and a liquid more or less transparent. The coagulum is white, with more or less of a pink hue; slightly elastic and fibrous; it is dissolved by the alkalis; the acids partially dissolve it, a fatty matter being precipitated. This substance Vauquelin regarded as similar to fibrin, or as intermediate in its properties between fibrin and albumen.



Mr Brande remarks, that it is more analogous to the caseous matter of milk. The liquid portion of chyle, which separates from the coagulum, is coagulated by heat. This coagulum is dissolved by the alkalis, but the solution remains turbid; it bears a considerable resemblance to albumen, and hence has been termed, by Dr Prout, *incipient albumen*. The chyle of a dog, according to Dr Prout, consists of above 90 *per cent.* of water, 4 of albumen, 4.6 of incipient albumen, less than one *per cent.* of fibrin, and the same quantity of saline matter, with a trace of sugar of milk.

MILK, the secreted liquid designed for the nourishment of young animals, though it differs somewhat in its properties in different species, appears to contain the same proximate principles. It is white and opaque, bland and sweet to the taste; its consistence is somewhat thick, and its specific gravity a little greater than that of water.

Milk, on remaining at rest after it has been drawn, suffers a slight decomposition; a thick bland fluid, the Cream, rises to the surface; this is of an oily nature. By agitation it is resolved into a fluid and solid part, the latter, Butter, having the properties of expressed oil. According to Berzelius, 100 parts of cream, of specific gravity 1.0244, consist of butter, 4.5, caseous matter, 3.5, and whey, 92. It appears that oxygen is absorbed from the air during the agitation by which butter is obtained from milk, whence the acidity that is acquired; at the same time, the temperature rises 3 or 4 degrees. This absorption is not, however, a necessary part of the process, as butter can be made though the air be excluded.

Butter, according to Chevreul, consists of a portion of whey and acid united to an animal oil. This oil, he farther states, is resolvable into the principle called Elain, and



a peculiar principle which he terms *Butyrine*. The latter is a fluid at the temperature of  $70^{\circ}$ . When converted into soap, it yields three volatile odoriferous compounds, namely, the butyric, capric, and caproic acids; these give the peculiar odour to butter.

Milk, after the separation of the cream, soon suffers another change; it becomes ascendent, and then coagulates, apparently from the reaction of the acid on the principle that separates, as acids, even the weakest, have the same effect. The coagulation is also produced by a number of neutral salts, by alcohol, by the gastric fluid of animals, the juices of plants, and even by heat. The gastric fluid taken from the stomach of young animals, or the liquid called *rennet*, prepared from the maceration in water, with the addition of a little salt, of the membrane of the stomach itself, is usually employed to afford it in its least altered state.

The substance thus separated is a peculiar principle, the Curd, or Cheese of milk. The cause of its separation is not ascertained. The effect of the gastric fluid in separating it, does not appear to depend on its acidity; as, when it is not sensibly acid, or is even rendered alkaline, it retains the coagulating property.

The Cheese, or Caseous Matter of Milk, when freed from adhering oily matter, is white or greyish, somewhat elastic, insipid when fresh, though it acquires taste when kept. It is insoluble in water. Exposed to the air in a humid state, it passes into putrefaction; but if dry, it can be preserved long unchanged. The fixed alkalis dissolve it, when their action is aided by a moderate heat, ammonia being exhaled from partial decomposition; and when an acid is added, sulphuretted hydrogen is evolved. Alcohol converts it into a fetid adipocirous substance. The acids dissolve it, but with more or less decomposition; ni-



tric acid disengages from it nitrogen gas. According to Gay-Lussac and Thenard, 100 parts of the pure caseous matter of milk consist of carbon 59.78, hydrogen 7.43, oxygen 11.41, and nitrogen 21.38. It contains in general 5 or 6 *per cent.* of phosphate of lime. Two peculiar principles have been discovered by Proust, in the caseous matter of milk, which he has named Caseic acid, and Caseous oxide. The former is obtained by keeping the curd of milk for several days in water, when acetic, phosphoric and caseic acids are produced, all saturated with ammonia, which is generated at the same time. The washings of the curd on evaporation yield a saline mass, slightly transparent, and tasting strongly of cheese; this is dissolved in alcohol, and boiled with carbonate of lead, which removes the phosphoric acid: the caseate and acetate of lead remain in solution, and are to be decomposed by sulphuretted hydrogen; lastly, by distillation, the acetic acid being volatile, is separated from the caseic acid. The latter is of the colour and consistence of syrup, reddens litmus paper, and has a sour and bitter taste, mixed with that of cheese; it soon becomes solid, forming a mass like honey. It precipitates the oxides of silver, gold, and mercury, but scarcely any of the other metallic oxides. With infusion of galls it forms a thick white precipitate; nitric acid converts it into oxalic acid. It exists in cheese in the state of caseate of ammonia, and gives the peculiar flavour. The caseous oxide remains after the action of alcohol on the saline mass before described. It is a bulky white powder; when purified by frequent washing it is tasteless, soft and friable; it is dissolved by hot water and by liquid potash, but not by alcohol or ether. It is often present in cheese in distinct grains, which are hard and gritty. Caseate of ammonia



and caseous oxide form from 30 to 50 *per cent.* of good cheese.

The Serum or Whey that separates from the coagulum of cheese, is a liquid of a yellowish colour and slight tenacity, and of a sweetish taste; 1000 parts of it consist, according to Berzelius, of 928.75 of water, 35 of the peculiar principle called Sugar of Milk, 1.95 of muriate and phosphate of potash, 6 of lactic (acetic) acid, and lactate of potash, and a trace of lactate of iron, and 0.3 of earthy phosphates. If to this 28 parts of caseous matter be added, it gives the composition of milk deprived of the cream. The principle called Sugar of milk, is obtained by evaporating whey to a syrup, and allowing it to cool, when this substance is deposited, and by solution in water and a second evaporation, is procured in white rhomboidal crystals. It has a sweet taste, but less so than common sugar; it is soluble in 7 parts of cold and 4 of boiling water; it does not undergo the vinous fermentation. Like starch it is converted into real sugar, by being boiled in very dilute sulphuric acid. Though its properties are different from those of common sugar, its composition is very similar. Its most important character is that of affording, when acted on by nitric acid, the acid called Saccho-lactic. To procure this, the sugar of milk is mixed with 4 times its weight of nitric acid, and heated; on adding water a copious white precipitate falls, which is this acid; oxalic acid remains in the liquor. It is also obtained by the action of nitric acid on gum, whence it has been termed Mucid acid.

Saccho-lactic or Sacclactic acid is in the state of a white granular powder; its taste is slightly sour; it is sparingly soluble in water, requiring 60 parts at  $212^{\circ}$  to dissolve it. The solution has an acid taste, and reddens the vegetable colours; it deposits small crystals on cooling.



The acid forms, with salifiable bases, salts named Saccho-lactates, or sometimes Saclactates, of which those with the alkalis are soluble and crystallizable, those with the earths and metallic oxides of sparing solubility. It consists, according to Berzelius, of 33.4 of carbon, 61.5 of oxygen, and 5.1 of hydrogen; whence it is inferred to be composed of six atoms of carbon, 36, eight of oxygen, 64, and five of hydrogen, 5, = 105, an equivalent which corresponds also with the analysis of saccho-lactate of lead.

The whey of milk, from the quantity of saccharine matter it contains, can be made to pass into the vinous fermentation, so as to afford a weak vinous liquor. It passes more readily into the acetous fermentation; the acid which is formed when it becomes acescent, was considered by Scheele to be a peculiar one, and was named the Lactic Acid. This opinion was also maintained by Berzelius; but it is now generally admitted to be merely the acetic acid, disguised by animal matter mixed or combined with it. This impure acetic acid exists in a number of the animal fluids.

The union of the saccharine and oily matter of milk, with the more animalized product, the cheese, renders it a fluid at once nutritive and easy of digestion, and the presence of the phosphoric acid with the lime and iron adapt it particularly as food for young animals, in whom such earthy matter is necessary for the formation of bone.

EGGS.—The properties of the recent egg, and the changes which it undergoes in incubation, have been particularly examined by Dr Prout. The recent egg is rather heavier than water, but by keeping becomes lighter, from a portion of water escaping through its pores, which is replaced by a quantity of air. Of an egg weighing 1000 grains, the white constitutes about 604 grains, the



yolk 290, and the shell 106 grains; it loses weight gradually during incubation, the loss being nearly a grain each day. An egg of ordinary size yields about three-tenths of a grain of soluble matter to boiling water. This consists of a portion of free alkali, a little animal matter, and sulphuric, phosphoric, carbonic, and muriatic acids, combined with lime and magnesia. The egg shell consists of carbonate of lime, with a little carbonate of magnesia, 2 *per cent.* of animal matter, and 1 *per cent.* of phosphates of lime and magnesia. In the yolk of the egg a considerable quantity of phosphorus, either free or in some unknown state of combination, exists; when the yolk is burnt, this substance is acidified, and forms a crust of phosphoric acid round the charcoal which remains. Heated alcohol, digested on the yolk, becomes of a deep yellow colour, and on cooling, deposits crystals of a sebaceous matter, and a quantity of a yellow oil: the portion of the yolk which remains undissolved by the alcohol is a white friable substance, resembling albumen, but differing in containing a considerable proportion of phosphorus. The white of the egg, which consists chiefly of albumen, contains also a little free sulphur, which, by combustion, is converted into sulphuric acid.

The phosphorus in the yolk must obviously be intended to afford phosphoric acid for the bones of the chick; but Dr Prout was unable to discover how lime was supplied to combine with it, none of this earth existing in the soft parts of the egg, and there being no apparent vascular communication between the shell and the chick.

SECT. III.—*Of Lymph, Mucus, Humours of the Eye, Synovia, Amniotic Fluid, Pus.*

LYMPH is a pellucid fluid, taken up by the absorbents



from the internal surfaces, or conveyed from the extremities of the arterial branches, and appears to be analogous to the serum of the blood. It is slightly viscid, is miscible with water, and is slightly coagulated by acids, and by alcohol. It contains albumen apparently with a minute portion of muriate of soda. The liquid of the pericardium, according to Dr Bostock, is of similar composition, consisting of water 92 parts, albumen 5.5, mucus 2, and muriate of soda 0.5. The serous fluid, which, in *Hydrocephalus internus*, is effused in the ventricles of the brain, consists, according to Berzelius, in 1000 parts, of water 988.3, albumen 1.66, muriate of potash and soda, 7.09, lactate of soda, (acetate of soda) and animal matter, 2.32, soda, 0.28, soluble animal matter, with a trace of phosphates, 0.35.

**Mucus.**—This fluid, which covers the passages and internal cavities of the body, appears to be the lymph in an inspissated state, its watery portion having been absorbed. The term mucus has been used, however, to denote a principle existing in the fluid which has usually received that name, as well as in other animal fluids. The characters assigned to it are solubility in hot and cold water, its solution neither coagulating nor becoming gelatinous when heated; but by evaporation it can be obtained solid, and be again dissolved. It is not precipitated by tannin, or by corrosive sublimate, but gives a copious white precipitate with Goulard's extract. According to Berzelius, there is no such principle well defined, the mucus of different parts differing in its properties.

The mucus of the nostrils appears to afford the purest form. As first secreted, it is liquid and clear, but from exposure to the air becomes thick and viscid; and, by the continued action of oxygen, becomes nearly concrete, a change at once produced in it by chlorine. In this state



it is not soluble in water, nor easily diffused in it; the acids thicken it, but in large quantity redissolve it. The alkalis do not exert on it any solvent power. It contains saline matter, principally muriate and carbonate of soda, phosphates of soda and lime.

The liquid which forms the tears is nearly the same, and, like it, contains carbonate of soda, so as to change the colour of violet to green, with muriate of soda, phosphate of soda, and phosphate of lime. The latter, when it accumulates, forms the basis of the concretions sometimes found in the lacrymal glands.

**HUMOURS OF THE EYE.** The ball of the eye contains three fluids, the Aqueous Humour in the anterior chamber; the Crystalline Humour, or Lens, in the central space; and the Vitreous Humour, filling the space behind the lens. The aqueous humour contains more than 80 *per cent.* of water, with a small quantity of albumen, muriate and acetate of soda, and a very little soda. The vitreous humour, when pressed out of its capsule, is found to be the same in composition. They are both transparent, with little smell or taste. The crystalline humour, in addition to the ingredients of the other humours, contains, according to Berzelius, nearly 36 *per cent.* of a peculiar animal matter, which approaches very closely in characters to albumen, if it is not that principle. The lens is solid, and composed of concentric lamellæ, which become more dense towards the centre. The mean specific gravity is 1.100. It putrifies rapidly. It is soluble in cold water, and is partly coagulated by heat; the coagulum resembles the colouring matter of the blood in every character but the colour.

**SYNOVIA.** This name is given to the liquor found with-



in the capsular ligaments of the joints, the motions of which it is evidently designed to facilitate, by lubricating the parts. It is viscous, of a greenish colour, and more or less transparent: when withdrawn from the capsule, it becomes gelatinous; after some time it again becomes fluid, and deposits a fibrous elastic matter. It mixes easily with water. Diluted acids throw down a substance in white threads, very similar in its properties to the gluten of wheat; it is soluble, however, by agitation in cold water. There remains, after its precipitation, a portion of albumen, which may be separated by heat, or by alcohol; the residual liquor gives crystals of muriate of soda by evaporation. From its analysis by Margueron, synovia appears to contain in 100 parts 80.46 of water, 11.8 of fibrous matter, 4.5 of albumen, 1.75 of muriate of soda, 7 of carbonate of soda, and 7 of phosphate of lime.

Arthritic Concretions, or those concretions often deposited in the joints during a paroxysm of the gout, are probably formed by the medium of this fluid. Dr Wollaston found that they consist of urate of soda.

AMNIOTIC FLUID. This is the fluid with which the foetus is surrounded in the amnios. Vauquelin stated, that he had discovered, in the amniotic fluid of the cow, a new acid, which he called the Amniotic Acid. He described it as forming crystals on evaporation, white and brilliant, having a slightly sour taste, reddening litmus, and soluble in alcohol and warm water; it did not appear to be present in the human amniotic fluid. Other chemists have been unable to detect this acid in any amniotic fluid; its existence is therefore doubtful. The liquor of the human amnios contains, according to Vauquelin, a small quantity of albumen and gelatin, with soda, muriate of soda, phos-



phate and carbonate of lime \*. In one instance, Dr Prout found also sugar of milk in this liquor.

PUS. This is the fluid secreted by an inflamed and ulcerated surface. When discharged from a healing sore, it is a thick yellowish fluid; its specific gravity is 1.03; examined by the microscope, it is found to consist of minute globules, swimming in a transparent fluid. It is inodorous, and when recent, produces no change on vegetable colours, but soon becomes acid; it is insoluble in water, is thickened by alcohol, is dissolved by strong acids, and is again precipitated on the addition of water. Ammonia converts it into a transparent jelly, and dissolves the greater part of it. It gives a white precipitate with nitrate of silver, and still more copiously with corrosive sublimate.

It has been considered of importance to discover some unequivocal chemical test, by which pus may be distinguished from mucus, as the mucus secreted in catarrh is often so changed in its appearance, that it is apt to be mistaken for the purulent expectoration in confirmed phthisis. The following tests of this kind have been given: When mucus and pus are diffused through water, the former floats, while the latter sinks. Likewise, when these fluids are dissolved in strong sulphuric acid, and water added, the mucus remains suspended, but the pus is precipitated. Thirdly, if they are dissolved in liquid potash, and the so-

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\* In several of the animal fluids, in which muriates of soda and potash are supposed to exist, with phosphate and carbonate of lime, it is not improbable that, in conformity with the principle applied by Dr Murray to the constitution of mineral waters, the real saline ingredients may be the more soluble compounds of muriate of lime, and phosphates and carbonates of soda and potash. ED.



lutions diluted, the pus is likewise thrown down, while the mucus continues in solution. An additional test has been given by Grassmeyer, said to be more certain than any of these. The fluid to be tried is to be triturated with its own weight of water, and an equal quantity of a saturated solution of carbonate of potash added; if pus is present, a transparent jelly will subside in a few hours, but this will not happen with mucus alone. It must be confessed, however, that none of these tests are decisive, as mucus secreted by diseased surfaces seems often to pass by insensible degrees into pus.

The fluid of Perspiration or Sweat has been examined by Berzelius, who found it to be chiefly water, with portions of muriate of potash and soda, acetate of soda, and free acetic acid.

SECT. IV.—*Of the Fluids subservient to Digestion, Saliva, Pancreatic, and Gastric Juices.*

THE Saliva, or liquor secreted by the salivary glands, and designed to facilitate the mastication of the food, is slightly viscid, and has a taste somewhat saline; it does not mix uniformly with water, but if diffused through it, it lets fall a quantity of mucus, which appears to be mixed with it. When the liquid, formed by triturating saliva with water, is exposed to heat, it is slightly coagulated, and it suffers the same change from alcohol, and the stronger acids, denoting the presence of albumen: the influence of galvanism was also found by Mr Brande to produce a slight coagulation. The fixed alkalis dissolve saliva, and disengage a small quantity of ammonia.

Saliva evaporated to dryness yields a very small pro-



portion of solid matter, not exceeding, according to Berzelius, 7 parts in 1000, the rest being water. Of this solid matter 2.9 parts are a peculiar animal matter, soluble both in alcohol and water, and which has been supposed to be osmazome; 1.4 are mucus, 1.7 alkaline muriates, 0.9 lactate (disguised acetate) of soda, and 0.2 pure soda. The saline contents in human saliva have been stated by Tiedemann and Gmelin to be chiefly muriate of potash, with small portions of acetate, carbonate, sulphate, phosphate, and sulpho-cyanate of potash. The presence in saliva of the sulpho-cyanic acid, an active poison, presents a singular fact, but one fully proved by the application of various tests \*, particularly by the deep orange-red colour which saliva produces with salts containing peroxide of iron. They found human saliva to contain but little soda. That of the sheep, in which they also detected a sensible quantity of sulpho-cyanic acid, differs in containing soda as the chief base, instead of potash; and this soda was in the state principally of phosphate of soda; this is also the chief salt in the saliva of the dog, which contains, however, no sulpho-cyanic acid.

The saliva is designed to facilitate the mastication and deglutition of the food, and to prepare the food in some measure for digestion by softening it. Tiedemann and Gmelin have supposed the use of the sulpho-cyanate of potash to be to destroy the contractility of the fibres of the food,—a singular notion, as such a contractility certainly does not exist in any food which man uses.

The concretions which sometimes form in the salivary glands, consist of animal matter, probably inspissated mucus, or albumen with phosphate of lime. The incrustation which forms on the teeth is of a similar nature.

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\* Med. and Surg. Journal, vol. xxvii. p. 420.



PANCREATIC JUICE.—The liquor secreted by the Pancreas, and apparently designed, like it, to facilitate the changes which the food is to undergo, has been supposed to be similar in nature and qualities to saliva; but, according to Tiedemann and Gmelin, it differs in several particulars. It contains chiefly albumen, with a little osmazome and animal matter, such as exists in saliva. It reddens litmus, it is supposed from the presence of free acetic acid. Its saline ingredients are similar to those of saliva, except that the sulpho-cyanic acid is absent.

GASTRIC JUICE.—The liquid secreted by the glands of the stomach, and subservient to the process of digestion, operates probably by its chemical agency: hence the importance of the investigation of its properties. Whether procured from the stomach of graminivorous or carnivorous animals, it appears to be the same in physical qualities. If unmixed with any of the food, it is clear; its taste is slightly saline; when taken from the stomach of an animal killed while fasting, it is neither acid nor alkaline. But during the process of digestion, it is found to be decidedly acid. Dr Prout first discovered that it contains free muriatic acid; he showed that this acid exists in the gastric juice of a number of animals, and that it is frequently present in considerable quantity in the stomachs of persons labouring under dyspepsia. This fact has been confirmed by Mr Children. Tiedemann and Gmelin have more recently shown, that the free acetic acid is also secreted in digestion along with the muriatic acid. They have likewise ascertained that the secretion of these acids commences as soon as the stomach is stimulated by the entrance of foreign bodies, as of food. Vauquelin found phosphoric acid always present in the gastric juice of herbivorous animals.



Spallanzani observed, that the gastric juice is little liable to putrefaction, that it preserves other substances from becoming soon putrid, and even restores the sweetness of animal matter which had become putrid,—observations to a certain extent confirmed by Stevens.

The most remarkable property of this fluid is the solvent power which it exerts on the food. Reaumur observed, that if the food on which an animal naturally subsists be inclosed in metallic tubes, so as to protect it from the muscular action of the stomach, but perforated so as to admit of the action of the gastric fluid, it is dissolved, in those animals particularly who have a membranous stomach, and live on flesh ; but in those who have a muscular stomach, capable of strong contraction, the solution is less complete, or is even frequently scarcely affected. This might arise from the trituration produced in the food by the muscular action of the stomach in those animals, facilitating the solvent action of the gastric fluid ; and accordingly, Spallanzani found, that when the food was previously bruised, and introduced into the stomach inclosed in tubes, it was dissolved. The solvent power, however, he found to be exerted much more quickly in those animals who have a membranous, than in those who have a muscular stomach ; and in some of the former this power is very great ; the hardest bone, inclosed in a tube, being speedily dissolved in the stomach of the eagle, or of the dog. He likewise found the same solvent power to be exerted by the gastric fluid out of the body, at a temperature of  $96^{\circ}$  or  $100^{\circ}$ , or not higher than that of the animal system. His experiments are confirmed in general by those of Stevens. He also found that the solvent power of the gastric fluid is in a great measure exerted on the food natural to the animal : thus birds of prey are quite incapable of digesting vegetables. In many species, how-



ever, the stomach appears to be capable of adapting itself, to a considerable extent, to the substance which it receives, so that an entire change can at length be effected in the habits of many animals, with regard to the food on which they can subsist. In those who feed both on animal and vegetable substances, both are dissolved by the gastric fluid.

The solvent power of this fluid is well shewn in its action on the stomach itself, which, in carnivorous animals especially, who die suddenly, and in a state of vigour, is sometimes found, a few hours after death, to be dissolved in its depending part,—a fact, too, which well shews how far the presence of vitality suspends the usual laws of chemical action, since it protects the stomach from the action of a liquid thus capable of dissolving it. These properties of this fluid cannot well be ascribed to any known chemical agency. Tiedemann and Gmelin indeed ascribe its solvent power to the energy of the free muriatic and acetic acids, and have endeavoured to shew that most substances used as food by animals are soluble in these mixed acids ; but the subject is still obscure and uncertain.

#### SECT. V.—*Of Bile, and Biliary Calculi.*

BILE, the liquor secreted by the liver, is probably in part excrementitious, and in part designed to promote the process of digestion, or chylication. It has the singularity of being secreted from venous blood ; and with this is probably connected its peculiar composition, in which carbon and hydrogen appear to predominate.

As first secreted, it is liquid, and in this state flows in part into the intestinal canal. A portion of it is received into the reservoir named the Gall Bladder, in which



it suffers inspissation; and it is this Cystic Bile, as it is named, which has been usually submitted to chemical examination. It is thick, and of a specific gravity greater than that of water; its colour is greenish-yellow; its odour faint; its taste intensely bitter. It suffers, in a short time, decomposition, and acquires an offensive odour.

Bile, when evaporated, affords a large quantity of water, having its smell, but not its taste. The residual matter, Extract of bile as it is named, is thick, of a dark-brown colour, deliquescent, and soluble in water.

Bile is soluble in water in every proportion, and its solution changes the colour of violet to a green, indicating the presence of a free alkali, which appears to be soda.

According to Thenard, 800 parts of the bile of the ox consist of water, 700, what is called resin of bile 24, picromel 60.5, yellow matter 4, soda 4, phosphate of soda 2, muriate of soda 3.2, sulphate of soda 0.8, phosphate of lime 1.2, and a trace of oxide of iron. The resin, he supposed, to be rendered soluble by the soda, and by the peculiar principle which, from its sweet and bitter taste, he named Picromel. Berzelius has given a different view of the constitution of bile; he does not admit the existence of either the resin or the picromel, but supposes them to constitute one principle, which forms with an excess of any acid an insoluble compound, and it is this which has been considered as the resin of bile; his view, however, has not been adopted. In addition to the principles which have been mentioned, there have been also detected in bile a principle called Cholesterine, which is the basis of biliary calculi, asparagin, gliadine and osmazome, or substances very similar to them, mucus and caseous matter, and some other principles, of which the characters and composition are yet uncertain. The saline matter consists, according to Tiedemann and Gmelin, of



soda united with carbonic, phosphoric, sulphuric, muriatic and acetic acids, also with the animal acids, the margaric, oleic, and a peculiar acid called the cholic, from existing in bile, distinguished by having a sweet taste: there is likewise present in bile a little phosphate of lime.

To obtain the Resin of bile, a mineral acid is added to that fluid, which throws down a greenish precipitate, consisting of the colouring matter of bile, with caseous matter and mucus; and after some time, margaric acid, and portions of picromel and resin, in union with the acid employed, subside. Acetate of lead is then added, which throws down most of the other acids, as the sulphuric, phosphoric, carbonic, and muriatic acids. The clear liquid is mixed with solution of subacetate of lead, (Goulard's extract,) when the resin and picromel are precipitated in combination with oxide of lead; the precipitate being diffused through water, and sulphuretted hydrogen transmitted through the liquor, sulphuret of lead falls down with the resin, while the picromel remains in solution. The resin is obtained pure by digesting the last precipitate in alcohol, and evaporating the solution. It is a solid substance, inflammable, fusible at  $120^{\circ}$ , soluble in alcohol, and precipitated from this solution by the affusion of water. When the resin has been in a great measure removed in this process the Picromel remains dissolved, and Thenard obtained it by simply evaporating this watery solution; but as thus procured, it always contains, according to Tiedemann and Gmelin, a portion of resin, whence the bitterness mixed with its sweet taste. It can only be separated by repeated solution and precipitation by subacetate of lead. When pure it has a sweet taste like that of sugar, which it much resembles in properties, but differs in constitution, containing a large proportion of nitrogen; it forms crystal-



line grains soluble in water and alcohol, but not in ether; it is not thrown down from its watery solution by acids, nor by acetate or subacetate of lead. It forms with the resin of the bile a soluble compound, which is precipitated by these agents: this compound has the bitter and sweetish taste peculiar to bile, and is the same with the picromel of Thenard.

The bile of other animals has not been so carefully examined as that of the ox, but, in general, Thenard found this fluid to be very similar in properties in those which he investigated. That of the pig, however, contained no picromel nor any albumen. That of birds, on the contrary, contained a large portion of albuminous matter.

In human bile, according to Thenard, no picromel can be discovered, and the chief ingredients are albumen, resin, yellow matter, and soda, with phosphates of soda and lime, sulphate and muriate of soda, and oxide of iron. Both picromel and cholesterine, however, have since been detected in human bile.

BILIARY CALCULI are concretions found in the gall bladder. Generally they are of a lamellated structure, and are composed of a substance which was regarded by Fourcroy as analogous to spermaceti, and to the principle called Adipocire. This solid matter, however, has been considered by M. Chevreul to be rather a peculiar principle, which he has named Cholesterine, (from *χολη* bile, *στερεος* solid.) It is described as a white crystalline substance with much lustre, insipid and inodorous, much resembling spermaceti, but differing in being less fusible, and in not forming a soap with alkalis. It is also converted by the action of nitric acid into a peculiar acid called Cholesteric acid; this is slightly soluble in water: it forms soluble salts with the alkalis: by a heat of  $212^{\circ}$ ,



it is decomposed. Cholesterine is readily soluble in boiling alcohol, but is again deposited in pearly scales in cooling; from this property, the method of obtaining it pure from biliary calculi is to digest them in boiling alcohol and filter the solution while hot, when on cooling it is precipitated. According to Chevreul, cholesterine consists of carbon 85.095, oxygen 3.025, and hydrogen 11.88. It has lately been detected in the bile itself, both in that of animals and of man.

Besides cholesterine, biliary concretions contain a portion of inspissated bile, and the yellow colouring matter of the bile in a concentrated state, which, from the beauty of its hue, and its permanence, is much valued as a pigment. This colouring matter is insoluble in water and alcohol, but is dissolved by liquid potash; the solution gradually becomes green, and the addition of an acid throws down a green precipitate. Muriatic and nitric acids change the yellow colour to green of various tints, it is supposed from the matter absorbing oxygen.

ERYTHROGEN is a peculiar substance which was discovered by M. Bizio of Venice, in the gall bladder of a person who had died of jaundice. Boiled in alcohol, it gave a solution which yielded rhomboidal crystals of an emerald green colour, transparent, insipid, and having the odour of putrid fish. It melted at  $110^{\circ}$ , resembling an oil; at  $212^{\circ}$  it became a purple or reddish colour vapour, whence its name (from *erythros* red.) It yields a similar red colour when acted on by nitric acid or ammonia; M. Bizio supposes it in these cases to unite with nitrogen, and to form with it a compound, the same with the colouring matter of the blood. Erythrogen has not been met with in any other than this single instance.



SECT. VI.—*Of Urine, Urée, Uric Acid, Urinary Calculi.*

THE fluid secreted by the kidneys is excrementitious, or is designed to convey from the body matter, which, if retained, would by its accumulation prove injurious to the system. The sole office indeed of the kidneys appears to be that of separating from the blood this matter, consisting chiefly of different salts and acids, and of substances containing a large proportion of nitrogen, by which any superabundance of that element is prevented. From these circumstances, the constitution of urine is extremely complicated, portions of every substance which is redundant in the circulating fluid being present in it, and some of these in the state of peculiar compounds; its chemical history is therefore of much importance, and has been the subject of laborious investigation.

According to Fourcroy and Vauquelin, the urine varies greatly at different periods of the day; that which they call crude urine, discharged soon after taking solid or liquid food, they found to contain little of the peculiar ingredients of the fluid; the proper urine is only voided six or seven hours after a meal. The quantity of this fluid is on an average from 30 to 40 ounces daily; in certain diseases gallons are sometimes discharged during the day.

When recently discharged, its colour is pale, its odour peculiar, but not fetid; it is transparent, but becomes turbid as it cools; a white cloud appears, consisting partly of the mucus of the bladder, partly of superurate of ammonia. Urine is sensibly acid, reddening the infusion of litmus: but, from the spontaneous changes it suffers producing ammonia, this acidity is soon neutralized, and it becomes alkaline. These changes continue to proceed,



mucous flakes are precipitated, the ammoniacal odour becomes strong and fetid, and the whole of the animal matter is at length decomposed, being converted principally into ammonia, combined with carbonic and acetic acids. Similar changes happen when urine is exposed to a gentle heat; its watery portion is dissipated, and carbonate of ammonia is formed and disengaged, the quantity increasing as the temperature rises.

The free acid existing in urine newly discharged, is principally the peculiar acid named Lithic or Uric Acid; it is often so abundant as to be in part deposited, forming, in combination with a portion of ammonia, the reddish sediment deposited as urine cools; with this there is generally present a portion of phosphoric acid, and, as Thenard states, of acetic acid; or, as it is termed by Berzelius, Lactic acid. According to the latter chemist, 1000 parts of urine consist of water 933, urée 30.1, uric acid 1, free lactic (acetic) acid, lactate of ammonia, animal matter and urée which could not be separated, 17.14, mucus of the bladder 0.32, muriate of soda 4.45, muriate of ammonia 1.5, sulphate of potash 3.71, sulphate of soda 3.16, phosphate of soda 2.94, phosphate of ammonia 1.65, earthy phosphates with a trace of fluuate of lime 1, silica 0.03. The fluuate of lime was discovered by Berzelius, by adding lime water to urine, and heating the precipitate which falls, with sulphuric acid, when vapours will arise, which corrode glass. Dr Prout is of opinion, that uncombined phosphorus exists in urine, and Proust concludes that sulphur is also present; gelatin has been supposed to be present, but this is uncertain. The silex is probably derived from the water used as drink. Vogel has also stated experiments, whence it appears that free carbonic acid exists in urine.

Though there is undoubtedly an excess of acid in urine,



yet, it is supposed by Dr Prout, that no acid properly exists in the fluid in an uncombined state, but that those which are in excess are in union with bases in the state of super salts. The principal of these appear to be the super-phosphates of ammonia and lime, and the super-urate of ammonia, the last of which forms the sediment deposited from urine, after standing for 24 hours. These salts do not perhaps all pre-exist in the urine; those in particular which contain ammonia, may derive a portion of it from what is formed by the combination of its elements during the evaporation.

When the entire matter obtained by the evaporation of urine is urged by a strong heat, it affords a large quantity of carbonate of ammonia, accompanied with a fetid oil, and with elastic products. Muriate of ammonia is sublimed, and towards the end of the distillation a small portion of phosphorus disengaged from the decomposition of the phosphoric salt is volatilized.

The effects of re-agents on urine afford some information with regard to the principles it contains, which renders its analysis more perfect. The acids have little immediate operation on it in its healthy state; after some time, however, crystals of uric acid are deposited, from the ammonia which held it in solution being neutralized; they sometimes coagulate or render it milky, an effect indicating the presence of albumen, from a morbid state of the secretion. Oxalic acid gives a precipitate by combining with the lime it contains. The fixed alkalis precipitate phosphate of lime; the solutions of lime, barytes, and strontites, or of any of their soluble salts, produce more copious precipitates, as they decompose all its phosphoric salts, and form with the phosphoric acid insoluble compounds; they also decompose any sulphates. The nitrates of silver and of lead form precipitates, from the



metallic oxide combining both with the muriatic and phosphoric acids of urine. Infusion of tannin generally occasions a cloudiness in urine, indicating the presence of animal matter perhaps, and in some morbid affections it produces even a copious precipitate.

Besides the saline substances in urine, it contains a peculiar principle, which giving to it some of its most characteristic properties had been named UREE. This may be obtained by evaporating urine to a thick consistence, when it is called Extract of urine, and treating it with alcohol; but a process which yields it in a purer state has been given by Dr Prout, which is usually followed. To the extract of urine, concentrated nitric acid is gradually added, till the whole becomes a dark coloured crystalline mass; this is slightly washed with cold water, dried on bibulous paper, and mixed with a solution of carbonate of potash, sufficient to neutralize the whole of the nitric acid; the solution is then concentrated by evaporation, when a part of the nitre crystallizes; the liquor drained from these crystals is mixed with animal charcoal, and after standing for some hours the urée is extracted from the mass, almost colourless, by cold water; this solution is evaporated to dryness, and digested with boiling alcohol, when the urée is dissolved alone, and is deposited in crystals on cooling. Urée thus purified has properties very different from what used to be assigned to it; it has not, as used to be stated, a strong urinous odour, but one faint and peculiar; its crystals are four-sided prisms, transparent, colourless, and having a slight pearly lustre; their specific gravity is 1.35. It leaves a sensation of coldness on the tongue like nitre. It does not affect litmus or turmeric: exposed to a moist atmosphere, it slightly deliquesces, but is not decomposed. When strongly heated it melts, and is partly decomposed, and partly sublimes. It



is soluble in an equal weight of water at  $60^{\circ}$ , and to an unlimited extent in boiling water. Alcohol at  $60^{\circ}$  dissolves a fifth of its weight of urée, and at a boiling temperature rather more than its weight; but it is not soluble in ether or oil of turpentine. The watery solution may be exposed to the air for months without change; but if any of the other principles of urine be mixed with it, it rapidly putrefies; ammonia and acetic acid are the chief products. If the solution of urée, in the impure state in which it was procured by Fourcroy and Vauquelin, be kept at a boiling temperature for some time, by adding to it fresh portions of water, it is almost entirely converted into carbonate of ammonia. When urée is decomposed by a strong heat, it emits an intolerably fetid odour, and yields a large proportion of carbonate of ammonia, equal to more than two-thirds of its weight, with a quantity of benzoic acid; and of carburetted hydrogen gas, leaving a portion of charcoal, with muriates of ammonia and soda. From its analysis by peroxide of copper, Dr Prout infers urée to consist of one atom of carbon 6, one of oxygen 8, one of nitrogen 14, and two of hydrogen 2; its equivalent is therefore 30 \*.

The acids act upon urée; sulphuric acid forms oil, ace-

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\* From this composition we are enabled to explain the peculiar character of urée, of being convertible, especially when boiled with water, into carbonate of ammonia. For, if we take 3 atoms of urée, and combine them with an equal number, or 3 atoms of water, we shall obtain precisely 3 atoms of carbonate of ammonia. Three atoms of urée will consist of 3 atoms of carbon, 3 of oxygen, 3 of nitrogen, and 6 of hydrogen: if to these there be added, 3 atoms of oxygen and 3 of hydrogen, we obtain a compound consisting of 3 atoms of carbon and 6 of oxygen, (carbonic acid,) and another of 3 atoms of nitrogen and 9 of hydrogen, (ammonia); and thus three atoms of carbonate of ammonia are produced.



tic acid, sulphate of ammonia and charcoal; muriatic acid dissolves it; chlorine disengages nitrogen and carbonic acid gases. Nitric acid poured on it heated evolves nitrogen, nitrous and carbonic acid gases, and produces ammonia and prussic acid. When nitric acid, however, is added to a solution of urée, it forms an insoluble compound with it, and this is one of the most delicate tests of urée. This precipitate is in scales, having a bright pearly lustre. Dr Prout found it to be a subnitrate of urée, consisting of one atom of nitric acid, 54, and two of urée, 60, = 114. It has been proposed by Dr Prout as a test for detecting the proportion of urée in morbid urine: a little of the urine is put into a watch glass, and by means of a dropping tube, a portion of nitric acid is introduced below it; if an excess of urée is present, spontaneous crystallization will happen, and according to the degree of excess, this will happen sooner or later, sometimes even in a few minutes, while in healthy urine it will not happen in less than half an hour. Oxalic acid produces with urée a similar insoluble compound.

The alkalis dissolve urée; the fixed alkalis at the same time cause an evolution of ammonia, partly from the decomposition of ammoniacal salts mixed with it, and partly from the decomposition of the urée itself; carbonic acid and acetic acid are at the same time formed, and a concrete oily matter is separated.

Urée has the property of changing the form of the crystals of various neutral salts; thus, muriate of soda crystallizes from a solution mixed with urée, not in its usual form of cubes, but in octohedrons. Solution of urée decomposes several of the metallic salts. Tannin changes the colour of its solution, but does not form with it any precipitate.

The tendency of this principle to pass to the state of



ammonia, is probably the cause of morbid changes in the urine, and may sometimes give rise to the formation of urinary calculi, by neutralizing the acid which holds some of the substances in urine dissolved. The predominance of nitrogen in its composition is a singular fact, and proves the developement of this element by the processes of the animal system, since its excess is thus discharged by an excrementitious fluid. In some morbid affections, particularly in diseases of the liver, it has been stated that urée is not present in urine.

URIC ACID is a substance peculiar to urine and urinary calculi, and with these its history is best connected.

Scheele discovered this acid as the principal ingredient of urinary calculi, whence he named it Lithic Acid; he found, too, that it is always contained in urine, forming the reddish-coloured sediment which it often deposits; as a common ingredient in urine it is named Uric Acid.

To procure it pure, the process given by Dr Henry is to dissolve a calculus composed of it in a solution of potash; this solution is decomposed by muriatic acid; the uric acid is precipitated, and is washed repeatedly with distilled water. It may also be procured in a similar manner from the solid urine of the Boa Constrictor. It is thus obtained in the state of a white powder. It is so sparingly soluble in water, as to require, according to Dr Prout, 10,000 times its weight at 60° to dissolve it; at 212° it is rather more soluble, and this solution on cooling deposits minute pellucid crystals. It reddens infusion of litmus, decomposes soap, and forms salts, called urates or lithates,—properties sufficient to characterize it as an acid, though some chemists have been inclined to rank it as an oxide. It is tasteless, and so weakly acid, as to be incapable of decomposing the alkaline carbonates; Dr Thomson affirms, however, that if it is boiled with



these carbonates for some time, the carbonic acid is expelled, its volatility being increased by the heat.

The salts formed by this acid are of sparing solubility, tasteless, and scarcely to be distinguished in appearance from the acid itself. The urate of ammonia is most soluble, and even of it an ounce of distilled water does not dissolve more than 2 or 3 grains at  $60^{\circ}$ ; next to it in solubility is the urate of potash. The alkaline urates become more soluble with an excess of base; and hence they are dissolved by boiling in an alkaline solution. These compounds, whether neutral or with an excess of base, are decomposed by all the acids, even the weakest, as the carbonic.

Uric acid is acted on in a singular manner by nitric acid. When a few drops of the latter are poured on solid uric acid in a watch glass, and a gentle heat applied, a solution of a rich red or purple colour is obtained, which becomes still deeper on evaporation to dryness. This is a character which serves to distinguish uric acid from every other substance. The cause of it will be immediately explained. When nitric acid is repeatedly distilled from uric acid, it decomposes it, carbonic acid and nitrogen gases are disengaged, and prussic acid and nitrate of ammonia formed. Muriatic acid has little effect on uric acid; chlorine passed through water, in which it is suspended, produces oxalic and malic acids, and muriate of ammonia.

Uric acid is decomposed by heat, affording carbonate of ammonia, carbonic acid, carburetted hydrogen, prussic acid, and a peculiar yellow matter which sublimes and condenses in a concrete form. When heated with peroxide of copper, the products are water, carbonic acid, and nitrogen. From its analysis by Dr Prout, it was inferred to consist of 2 atoms of carbon, 1 of oxygen, 1 of nitrogen,



and 1 of hydrogen; more lately its composition has been stated at 6 atoms of carbon, 3 of oxygen, 2 of hydrogen, and 2 of nitrogen, which would give an equivalent of 90. Dr Thomson is of opinion, however, that in this last analysis by Dr Prout, the crystallized uric acid contained 2 atoms of water, and deducting these, dry uric acid will consist of 6 atoms of carbon, 1 of oxygen, and 2 of nitrogen, which will give 72 for its equivalent.

The peculiar matter which sublimes when uric acid is heated, is regarded as a peculiar acid, and has been called the Pyro-uric. Its taste is slightly sour and bitter; it is more soluble in water than uric acid; is volatilized by a moderate heat without decomposition, and does not give a red colour with nitric acid. Its solution in water reddens infusion of litmus. By evaporation it affords minute crystals; it combines with the alkalis, and is not precipitated from these solutions by the acids; neither does it precipitate the earthy salts. In some of its properties it is analogous to succinic, in others to benzoic acid; but still it differs from either. It is inferred to consist of 12 atoms of carbon, 14 of oxygen, 25 of hydrogen, and 3 of nitrogen, which will give the large equivalent of 251.

**PURPURIC ACID.**—An acid may be obtained by the decomposition of uric acid, which may here be noticed. It has been mentioned, that when uric acid is digested in dilute nitric acid, the solution becomes of a beautiful purple or pink colour. This, according to Dr. Prout, is owing to a peculiar acid being formed, which, from its power of forming purple coloured salts, he has named the Purpuric, and in this experiment he conceives it to be produced in union with ammonia. The method which he has given for obtaining it uncombined is to dissolve pure uric acid in dilute nitric acid, to add ammonia until



the solution becomes neutral and evaporates, when dark red crystals of the purpurate of ammonia will be formed. These are to be dissolved in dilute solution of potash, and heat applied until the colour disappears; dilute sulphuric acid is then to be added, which saturates the alkalis, and precipitates the purpuric acid. Though this acid forms coloured compounds, it is itself white or colourless, with a pearly lustre, insipid, inodorous, and almost insoluble in water. It is dissolved by acids and by alkalis; when aided by heat it expels carbonic acid from alkaline carbonates, and forms salts called Purpurates. The solutions of these salts have a deep rose-red colour; this is particularly conspicuous in the purpurate of ammonia, which is supposed by Dr Prout to give the colour to the pink sediment deposited from the urine in cases of fever. The purpuric acid itself yields a purple colour with nitric acid, as if uric acid had been employed. Dr Prout inferred it to consist of 2 atoms of carbon, 2 of oxygen, and 1 of nitrogen; but he has not expressed much confidence in this analysis. The existence of the acid has been questioned by Vauquelin, Brugnatelli and Lassaigne, who are of opinion, that it is an oxygenated uric acid, which, when pure, forms colourless compounds, and that the purple colour is owing to impurity.

Another acid has been described by Brugnatelli, as obtained from the action of nitric acid on uric acid, which he has called Erythric acid, from its becoming red on exposure to the air, or when moistened. It appears, however, to be merely the purpuric acid combined, as Dr Prout supposes, with nitric acid and a portion of ammonia.

ROSACIC ACID.—This name was given by Proust to what he conceived to be a peculiar acid existing in the



rose-coloured *lateritious sediment*, as it is termed, which is deposited from the urine in some stages of fever, at the close of paroxysms of gout, and other diseases. He considered it to differ from the uric acid in being very soluble in hot water, in being scarcely crystallizable, and in throwing down a violet coloured precipitate from oxide of gold. Vogel has shown, however, that it is easily converted into the uric acid, and differs little from it. Dr Prout is of opinion, that it consists chiefly of purpurate of ammonia, derived from uric acid, which has been acted on by nitric acid in the urinary organs or passages; and as he has detected nitric acid in the urine from which it subsides, this supposition is one not improbable.

The composition of urine varies in different species of animals. In those which feed on grass, the uric acid is wanting, while benzoic acid is often present; and this is sometimes the case in the urine of children. The urine of the horse and cow contains no phosphates, but muriates, sulphates, and carbonates of potash and lime with urée; that of the former contains a large proportion of the carbonate of lime. The urine of birds of prey has been found, by Dr Wollaston, to contain a large quantity of uric acid; and the excrement of the serpent, called the Boa Constrictor, which also feeds entirely on flesh, consists, according to Dr Prout, almost wholly of this acid. On the other hand, Vauquelin found that the urine of the lion and tiger, though fed on flesh, altogether wanted this acid, containing, instead of it, a large quantity of urée and of ammonia.

The composition of urine is considerably diversified by morbid states of the system. In the disease named Diabetes, sugar is secreted by the kidneys, and often in much abundance. The urée is at the same time deficient in quantity; indeed, it has been affirmed, in some cases, to



have been altogether absent, as the urine afforded no scaly precipitate on the addition of nitric acid. Dr Henry, however, has shown, that when urée is mixed with a large quantity of sugar, it does not give a precipitate with nitric acid; it is hence very doubtful if urée is ever altogether absent. On comparing the constitution of urée with that of sugar, they appear to differ only in the latter containing an additional atom of carbon and one of oxygen, instead of an atom of nitrogen; the formation of diabetic sugar probably therefore depends on a vitiated assimilation or secretion, by which the nitrogen is excluded, and, instead of it, additional atoms of carbon and hydrogen are communicated to the urée; and perhaps the mode of treatment which has been found most successful in diabetes, that of using only animal food, may, by preserving a constant excess of nitrogen in the system, lead to the establishment of the natural secretion. Diabetic urine is of a pale colour; it is not liable to putrefy, but has a tendency to undergo the vinous fermentation. In dropsy, albumen is often contained in urine in such a quantity, that it resembles the serum of the blood, and is coagulated by acids and by heat; and Dr Prout has mentioned cases, in which coagulation even happened within the bladder. In inflammation of the liver the urée is very deficient in quantity. In some nervous diseases, as hysteria, the urine contains a large proportion of saline, but scarcely any animal matter. In jaundice the bile sometimes passes by the circulation into the kidneys, and communicates a yellow colour to urine; its presence is detected by adding muriatic acid, which changes the colour to green.

One chief office of the kidneys is that of acidifying certain elements of the blood which pass through them; in this way they produce sulphuric, phosphoric and uric acids. Sometimes this function is performed to excess,



whence a superabundant and excessive quantity of phosphoric and uric acids is formed, and even new acids, as the oxalic, and it is said the nitric, are generated. These subvert the usual constitution of the urine, and give rise to one of the most formidable diseases to which man is subject, that of calculus or stone in the bladder. The same consequence also sometimes happens when the acid in the urine is deficient. The chemical history of these concretions is one of much importance, from its relation to the discovery of the means by which their formation may be prevented, or by which they may be removed.

URINARY CALCULI are of very variable characters and composition. To Scheele we are indebted for a knowledge of the most common of them, that composed of uric acid. The subject has been since ably prosecuted by various chemists, particularly by Dr Wollaston, who, in 1797, distinguished the principal species, and detected principles in them, of which the presence had not been suspected. Two years afterwards an elaborate memoir on Calculi was published by Fourcroy and Vauquelin; but nearly all the facts of importance announced in it, as discoveries, had been anticipated by Dr Wollaston. The following substances enter into the composition of urinary concretions,—uric acid, urate of ammonia, phosphate of lime, phosphate of ammonia and magnesia, oxalate of lime, silex, sometimes even oxide of iron, and animal matter; these being more or less pure, or mixed, and being often diversified by mechanical structure, so as to render it difficult to constitute well-defined species. The principal varieties may be included in six species; 1st, That composed chiefly of uric acid; 2d, That consisting chiefly of the triple phosphate of ammonia and magnesia; 3d, The Bone-Earth Calculus, formed almost entirely of phosphate



of lime; 4th, The Fusible Calculus, composed of the two preceding intermixed; 5th, The Mulberry Calculus, consisting of oxalate of lime; and 6th, A rare species, the Cystic Oxide Calculus. Two others, still more rare, are the Xanthic Oxide and Fibrinous Calculus, discovered by Dr Marcet; and, lastly, Calculi have been met with formed of carbonate of lime.

1st, Uric Acid Calculus. This is the most common species, forming indeed more than one half of the calculi that have been met with: calculi of this kind vary from the size of a bean to that of a large egg. They are of a brown or yellowish colour, smooth, displaying internally a fibrous or radiated structure, and usually consisting of fine layers of different shades, rather hard, with a specific gravity from 1.276 to 1.786. They are not melted by heat, but charred, exhaling an empyreumatic odour, and are almost entirely consumed. They are insoluble in cold water, but dissolve when boiled in water. Alkaline solutions dissolve them readily in the cold, and a white precipitate is thrown down by the addition of an acid. Lime-water dissolves them more sparingly. Nitric acid produces the red colour characteristic of uric acid; the other acids act weakly on them. In many the uric acid is nearly pure, in others it is intermixed with other ingredients. A rare species of calculus was noticed by Fourcroy and Vauquelin, consisting of Urate of Ammonia, the existence of which was doubted by some chemists, but has been established by Dr Prout. It is less sensibly striated, and its colour is lighter than the pure uric acid calculus; and it is distinguished by the chemical character of dissolving in alkaline solutions, and exhaling a smell of ammonia, two properties which are not found together in any other species. It decrepitates before the blowpipe.

2d, Calculus of Phosphate of Magnesia and Ammonia,



A concretion is scarcely ever formed of Phosphate of magnesia and ammonia alone. This salt is either discharged pure, under the appearance of a white sand, composed of minute shining crystals, forming *white gravel*, as a deposition of uric acid forms *red gravel*; or it is intermixed with other ingredients, particularly uric acid and phosphate of lime, and often forms alternate layers of these, or covers a nucleus of uric acid. It is distinguished by its softness and smoothness, its white colour, its lamellated texture, and its giving a fine powder of brilliant whiteness, which has a sweetish taste. Before the flame of the blowpipe it blackens and emits an ammoniacal smell; a white powder remains, which is fused with difficulty. It dissolves very sparingly in boiling water. The acids, even those that are weak, dissolve it easily, leaving any animal matter mixed with it undissolved. The fixed alkalis disengage its ammonia, and precipitate the magnesia. The urine, as Mr Brande has remarked, has at all times a tendency to deposit a portion of triple phosphate upon any body over which it passes; hence drains, by which urine is carried off, are often incrustated with its regular crystals; and in cases where extraneous bodies have entered the bladder, they have in a short time become covered with a coat of the same substance.

3d, Calculus of Phosphate of Lime. This sometimes composes the entire substance of a concretion; more frequently it is mixed either with uric acid or with phosphate of magnesia and ammonia, or disposed with them in layers. When pure or little intermixed, the concretion is of a pale brown colour, and so smooth as to appear polished; its texture is laminated, in a very regular manner, and it may be separated with little difficulty into concentric crusts. It dissolves slowly, but entirely, in muriatic or diluted nitric acid, and it is little affected by alka-



line solutions. Before the flame of the blowpipe it is at first charred, but soon becomes white; and, if the heat be raised very high, is fused.

*4th*, Fusible Calculus. Neither of the preceding species are often met with singly, but in a state of intermixture they form this variety, which next to that of uric acid is the most common urinary concretion. Its peculiar character is that of readily fusing before the blowpipe into a white vitreous globule, its constituents acting as fluxes to each other. It is a very friable concretion, of a white colour resembling chalk, sparingly soluble in water, but easily dissolved by acids. It may be analysed by placing it in acetic acid, which dissolves the phosphate of ammonia and magnesia, and leaves the phosphate of lime. Calculi of this kind are often of a large size, and there have been instances in which they filled almost the whole of the bladder.

*5th*, Calculus of Oxalate of Lime. This has been long known by the name of Mulberry Calculus, from its colour and its rough-pointed surface. Dr Wollaston shewed that it consists chiefly of oxalate of lime, with animal matter. It is of a dark-brownish or purplish colour externally, derived, it is supposed, from effused blood; it is often grey within; its surface is usually uneven, often covered with protuberances; it is the hardest and the heaviest of the urinary calculi. It is also less affected than any of them by the usual re-agents. The alkaline solutions do not affect it, and the stronger acids, nitric and muriatic, dissolve it with more facility. The solutions of the alkaline carbonates decompose it, precipitating carbonate of lime. It is also decomposed by heat, leaving, when urged by a strong fire, pure lime, amounting to about one-third of its weight; it is principally the animal matter which gives it hardness and closeness. It is not



an uncommon concretion, and is still more frequently the nucleus of calculi; indeed it would appear that almost all concretions originate in the precipitation from the urine of a small quantity either of uric acid or of oxalate of lime. This happens commonly in the kidney: if the nucleus does not soon escape by the ureter, it there increases by deposition on its surface, but usually it reaches the bladder, and grows in size by the formation of successive crusts on its surface. One-third of the number of calculi, it is calculated, arise from nuclei of oxalate of lime.

According to Mr Brande, persons who have voided this species of calculus are much less liable to a return of the complaint than those who have discharged uric acid calculi, probably from the former being more an accidental formation than a product of a settled habit of secretion. It is a very general opinion, that the mulberry calculus is the most painful and dangerous species,—an opinion apparently justified by its rough tubercular surface, its hardness and weight, whence it might be supposed to cause the greatest irritation and injury to health. This, however, is not the case: on the contrary, it is stated by Dr Prout, that the phosphatic calculi, which are the lightest and smoothest, are accompanied by the most severe pain and general suffering, a proof that the suffering does not arise so much from the mechanical irritation of the bladder by the stone, as from the intensity of the general diathesis. It appears also, that while the proportion of deaths after the extraction of calculi of uric acid, or the earthy phosphates, is about 1 in 6 or 7, in cases of mulberry calculi it is not 1 in 20.

*6th*, Calculus of Cystic Oxide. This species, discovered by Dr Wollaston, in 1805, is one of very rare occurrence. Its structure is confusedly crystallized, its colour yellowish, with a degree of lustre, and semitransparency. Be-



fore the blowpipe it is consumed, emitting a peculiar and very fetid odour. It is insoluble in water and alcohol, but is readily dissolved both by alkalis and acids, and these compounds may be obtained crystallized. From these properties, and its not affecting vegetable colour, it was named Cystic oxide, being supposed to originate in the bladder. Dr Marcet, however, has seen instances in which its formation could rather be traced to the kidneys. According to Lassaigne, who found cystic oxide in a calculus from a dog, it consists of carbon 36.2, oxygen 17, nitrogen 34, and hydrogen 12.8.

The other species are extremely uncommon. The Xanthic oxide is described by Dr Marcet as of a reddish colour, soluble both in acids and alkalis, and its solution in nitric acid assumes on evaporation a rich lemon colour, whence its name. The Fibrinous calculus he described as resembling fibrin. Carbonate of lime has in a few instances been found forming a calculus.

In all these calculi, besides the saline matter, there is present a portion of animal matter, which appears to be the mucus of the bladder: this seems to give them colour and induration: it is found even in those which are white and crystalline; in the mulberry calculus, it is present in larger quantity than in the others. The ingredients of calculi are often also diversified by intermixture in layers. These must of course be various, and, as their production is in some measure accidental, irregularly arranged. Those which have been most frequently observed are alternations of uric acid with phosphate of magnesia and ammonia, or phosphate of lime; or of oxalate of lime with the uric acid, or with either or both these phosphates.

With regard to the causes of the formation of calculi, no certain statement can be given. In the greater number of instances, they arise from the deposition of uric



acid; and this may happen from two causes,—either from an excess of uric acid in the urine, or from the presence of a free acid in considerable quantity. A redundancy of uric acid has been supposed by Magendie, and with much probability, to be in part owing to the habitual use of animal food, which generates an excess of nitrogen in the system. In general, this element is removed in the state of combination, which constitutes *urée*; but it may be conceived, that from morbid secretion, the *urée* may be acidified and converted into uric acid, as the difference in the composition of these two principles is not great. Though the uric acid is not in excess in urine, it yet may be precipitated by a free acid; this, according to Dr Prout, is usually the phosphoric, which, in general, serves the important office of retaining the earths and the mucus of the bladder in solution, but when superabundant, unites with the ammonia, with which the uric acid is combined, and thus throws down the latter acid. On this view, we are enabled to explain how the alkaline remedies frequently administered in calculus may, without being conveyed into the bladder, prevent the deposition of uric acid by saturating the excess of phosphoric acid. Dr Prout mentions, that he has observed, that unfermented bread, and heavy hard boiled puddings and dumplings, produce a remarkable deposition of uric acid from the urine.

As to the triple phosphate of ammonia and magnesia, Fourcroy supposed it to be produced by ammonia being generated within the bladder by a change in the urine analogous to incipient putrefaction, and that when formed, it unites with phosphoric acid, and these abstract magnesia from the sulphate of magnesia in urine, and form the insoluble triple phosphate. This opinion is one very improbable. Dr Prout has supposed, rather that the



error is in the kidneys, which become unable to acidify all the phosphorus that passes through them, and thus, instead of a quantity of phosphoric acid being generated sufficient to form soluble salts with the earthy bases, there is only enough to form the insoluble neutral compounds. The presence of a calculus in the kidneys or bladder seems always to excite a precipitation of earthy phosphates; hence Dr Prout states, that whatever be the original diathesis, the phosphatic is always ultimately induced, and when established, it has a much greater influence over the whole constitution, producing suffering so severe, as to be of itself one of the surest indications of the state of the urine. When induced also, it can neither be changed, nor does it admit of much palliation; hence the removal of the calculus by an operation is the only cure for it.

No plausible theory can be given of the origin of oxalic acid; it may, perhaps, be generated by some change produced in urée by diseased secretion; and the similarity in some particulars between urée and sugar, which is easily convertible into this acid, is in favour of this supposition. Whenever it is generated, it will immediately unite with any lime that may be present, forming a precipitate.

An important subject of investigation, arising from our knowledge of the nature of urinary concretions, is that relating to the practicability of their solution, and the means by which this may be accomplished. If we add a portion of an acid to urine, red crystals of uric acid are deposited; if, on the other hand, an alkali is added, a precipitate is produced of triple phosphate, mixed with phosphate of lime. It is on these two facts, that all attempts at solution or palliation by chemical agents are founded, as they shew, that when there is a tendency in



the urine to deposit uric acid, acids must be hurtful and alkalis beneficial, while, when a white sediment of earthy phosphates subsides from the urine, the reverse will happen, alkalis will be injurious, and acids ought to be administered. The internal administration of alkalis in cases of calculi of uric acid, which are the most common, is a practice that has long been had recourse to; and it has been ascertained, that the urine may receive, to a certain extent, an alkaline impregnation, from which considerable relief is obtained: it has even been supposed, that a solvent power may thus be exerted on the calculus, if it is of a moderate size. In other cases, where the deposition from urine has consisted chiefly of the earthy phosphates, advantage has been derived from the use of the muriatic and nitric acids; and with regard to these also, it has been imagined, that a calculus composed of phosphates might be dissolved by their continued administration.

So far as relieving the pain and irritation which attend calculi of either kind, there can be no doubt of the advantage derived from the moderate use of their appropriate solvents; and these may, even in some measure, lessen the deposition of calculous matter. But there is much reason to doubt of the practicability of giving either of them to such an extent as to obtain the actual solution of a calculus, owing to the irritation they are liable to produce in the stomach and bladder. The observations of Mr Brande have also placed in a clearer light the impracticability of the attempt; for rendering the urine alkaline, so as to enable it to act on a calculus of uric acid, may, and often does cause the deposition of the earthy phosphates; or if, on the other hand, the solution of a calculus composed of these phosphates is attempted, by giving acids, there is the hazard of producing a precipi-



tate of uric acid ; nor is it probable that the alternate exhibition of these can be so adjusted as to produce the beneficial effect without occasionally giving rise to the opposite injurious consequences. And it is not improbable, as Sir E. Home suggested, that in instances where the continued use of alkalis has been stated to be successful, the calculi being found to be soft and porous on the surface, these appearances may have, in reality, arisen from deposition of earthy phosphates caused by the alkaline remedies. All that is practicable probably is, the giving the remedy, whether acid or alkali, so far as to render the urine less irritating, and thus alleviate the pain. The deposition of uric acid is the most frequent ; hence alkaline remedies are most generally employed. The celebrated remedy of Mrs Stevens consisted of lime and soap, and was found to be of considerable benefit. It has been found also, that the alkalis are equally efficacious, though combined with carbonic acid ; hence, bicarbonate of potash or of soda is frequently administered. Even the alkaline earth, magnesia, has been used, and with advantage, probably from its neutralizing the acid in the stomach, the excess of which appears to occasion the excess of acidity in the urine ; and it can be more safely employed, as it is not liable to be secreted by the kidneys, so as to cause any deposition of the earthy phosphates of the urine.

It was proposed by Fourcroy and Vauquelin, to employ lithontriptic medicines in another mode, by directly injecting them into the bladder. This is obviously a method attended with some hazard, from the great irritability of the bladder. If followed with caution, however, it may be equally safe, and promises to be more efficacious than when the chemical agents have to pass through the circulation before they can reach the calculus ; several trials of



it were made by Fourcroy, and subsequently by Dr Marcet, which were attended with favourable results.

It has been lately proposed by Prevost and Dumas to attempt the solution or disintegration of calculi in the bladder, by the application of galvanism, which may separate the constituent parts: but it is very unlikely that the power of this agent, applied in such circumstances, will produce any considerable effect.

SECT. VII.—*Of the Skin, Cellular Fibre, and Membrane.*

THE soft solids enumerated in the title of this section are closely connected, having the principle named GELATIN for their basis. The peculiar character which distinguishes it, is that of dissolving in warm water, and forming a solution which, when cold, becomes a tremulous transparent jelly, more or less firm, according to the proportion of water: even when dissolved in 100 parts of hot water, it forms a solid mass on cooling. It is obtained from all these substances by boiling; and they are at the same time more or less completely dissolved. Berzelius has supposed, that it is rather formed during the boiling from decomposition of the animal matter, but of this there is no proof. It forms also a considerable part of cartilage, tendon, and bone. It exists only as a constituent part of the animal solids, and does not appear to be contained in the blood, or any of the other animal fluids, as was at one time supposed. Besides the character of the gelatinous consistence which its solution assumes, it forms an insoluble compound with tannin; and this affords a test by which it is discovered. Corrosive sublimate does not precipitate it, by which it is distinguished from albumen. The acids dissolve it; the sulphuric, it has been shewn by



Braconnot, acts in a remarkable manner, converting it into a species of sugar. To obtain this, powdered glue is mixed with twice its weight of concentrated sulphuric acid, afterwards diluted with water, and boiled for several hours; then, on removing the acid by chalk, and evaporating, crystals are procured of a sweet taste, very similar to sugar. This saccharine matter differs from common sugar in being less soluble in water, in not fermenting with yeast, and in containing nitrogen, as appears by its yielding ammonia when heated. Gelatin is dissolved by the alkalis, and is not again precipitated by acids, a character which distinguishes it from albumen and fibrin. Analyzed by Gay-Lussac and Thenard, by means of the chlorate of potash, 100 parts of gelatin appeared to consist of carbon 47.881, oxygen 27.207, hydrogen 7.914, and nitrogen 16.998; a result, however, probably inaccurate, as it gives nearly the same proportions of these elements as Dr Prout's analysis of albumen. When moist, gelatin is very susceptible of spontaneous decomposition; when dried however, as in glue, isinglass, and the tablets of portable soup, it may be kept any time without change.

The SKIN, which forms the external covering of the body, consists of the Cuticle, or Epidermis, and beneath this the Cutis, or true skin, with a cellular substance interposed. The Cuticle is nearly inorganic; when detached from the parts beneath, it is thin and transparent. It is insoluble in water and in alcohol. Alkaline solutions dissolve it, forming a kind of soap. Lime also dissolves it. The acids decompose it, sulphuric acid forming a soapy pulp, nitric acid staining it yellow. The true Skin is thicker than the epidermis, and has considerable firmness and elasticity. If boiled strongly in water it is dissolved, and the solution has the characters of gelatin, being precipitated by tannin and nitro-muriate of tin, and



attaining, when evaporated, a gelatinous consistence. Even in its dense state it combines with tannin, whence the change it suffers in the operation of tanning. Acids decompose skin; nitric acid, which acts on it most readily, causing an evolution of nitrogen gas and prussic acid, and a formation of oxalic acid. In its humid state, it is liable to putrefaction. The Cellular Fibre between the cutis and cuticle has been little examined. It is the seat of the colour of the surface of the body, and the colouring matter diffused through it can be acted on through the cuticle, the skin of the negro being whitened, though not permanently, by chlorine.

The MEMBRANES, which compose a large portion of the soft solids, forming the cellular texture, the coats of the vessels, and the coverings of the viscera, appear to be of the same nature. They have similar flexibility, and dissolve in water, forming gelatinous solutions.

GLUE is gelatin prepared by boiling the skin and membranes of animals in water strongly, and reducing the solution by evaporation so far, that on cooling it becomes concrete. It differs in the degree of consistence which it gives to water, as prepared from different substances. Isinglass is nearly pure gelatin, prepared from the sounds of some fish, particularly the sturgeon.

#### SECT. VIII.—*Of the Muscular Fibre.*

THE Muscles, or Flesh of animals, have a distinctly fibrous texture. Their basis appears to be Fibrin not much changed, with which are intermingled small portions of albumen, gelatin, an extractive and saline matter, these being derived in part from the blood diffused by the medium of the blood-vessels. To this, too, the colour is



owing, as when washed with water the muscular substance remains white. The water employed in this operation holds dissolved the other principles. When heated, the albumen is separated by coagulation in flakes; if these are removed, and the liquor evaporated, it becomes gelatinous, a little fatty matter separating and collecting on the surface; and by this experiment the albumen and gelatin are detected. Besides these, a portion of a peculiar extractive matter, called Osmazome, is obtained by evaporating the jelly to dryness, and treating it with alcohol, the alcohol dissolving the osmazome, and yielding it, by evaporation, in a solid form. It is of a brownish colour, has a pungent odour, and a strong and pleasant taste, like that of the juice of meat; the taste and odour of soup and broth are supposed to be owing to it. It differs from other animal principles in being soluble in water and alcohol, whether cold or warm, and in not forming a jelly when its solution is evaporated; it is precipitated by infusion of galls. The saline matter in flesh is procured by boiling water on the muscular fibre, previously washed; it consists of phosphates of soda and ammonia, and phosphate and carbonate of lime. The proportions of these differ at different periods of life, being more abundant in the coarse and rigid muscular fibre of adult animals, than in the more delicate fibre of those who are young. In the latter the proportion of gelatin is larger than in the former. When these have been extracted, the fibre remains, which has all the qualities of the fibrin of the blood. When the flesh, without preparation, is boiled in water, the gelatin and albumen are more completely dissolved, and the fibrin is diffused in threads in the boiling liquor. The albumen coagulates, the gelatin is detected by the precipitate formed with tannin, or if the liquor be sufficiently evaporated, it forms a jelly.



When the muscular substance is exposed to the air, it soon becomes tainted, and at length putrid, a change principally arising from the presence of gelatin, which is peculiarly liable to putrefaction when humid; and accordingly, if it has been removed by washing, the flesh remains much longer sound. If the air is excluded, and the flesh immersed in water, it is gradually converted into a fatty substance, a species of decomposition which is afterwards to be considered.

SECT. IX.—*Of Tendon, Ligament, Cartilage, Horn, &c.*

THESE substances appear to have albumen for their basis; they also contain a portion of gelatin; they pass insensibly into each other, and they form the transition into shell and bone.

The TENDONS have a considerable degree of toughness and elasticity; their texture is fibrous. By long boiling they are in a great measure dissolved.

The LIGAMENTS are fibrous in their texture, and have much firmness and cohesion. When boiled in water, they afford a portion of gelatin, but the entire substance cannot be dissolved, and it probably, therefore, consists of indurated albumen.

CARTILAGE has a greater degree of induration. It is, however, sufficiently soft to be cut easily; it has also much cohesion and elasticity. It is softened by maceration in water, and the softer cartilages are, by boiling, nearly entirely dissolved. Acids do not exert much action on the matter of cartilage: when diluted or weak, they do not dissolve it; alkalis dissolve it. The base of cartilage appears to be coagulated albumen nearly pure.

HORN has a considerable similarity to cartilage, differ-



ing from it principally in greater induration. When boiled strongly in water, it affords a small quantity of gelatin, the most flexible horn yielding the largest quantity; the residual matter is indurated albumen, with a little phosphate of lime. It is singular that the horn of the stag is of a different nature, consisting principally of gelatin, with phosphate of lime, and being therefore analogous to bone. Hoof is, in mechanical structure and chemical composition, similar to horn; as are also the matter of the Nail, the Scales of insects, Feather and Quill; all of these when boiled in water giving scarcely any gelatin, but consisting apparently of indurated albumen. The scales of fish are different, consisting of alternate layers of membrane and phosphate of lime.

HAIR, according to Vauquelin, consists of a matter very similar to indurated albumen, insoluble in boiling water, but which may be entirely dissolved, by using a Papin's digester. This solution gave a black precipitate with nitrate of silver, and it is known that this salt stains the hair of a dark colour: these effects are ascribed by Vauquelin to the presence of a portion of sulphur in hair. The hair also contains an oily matter, which may be abstracted by alcohol macerated on it; in this the colouring matter appears to reside, as it is always obtained of the colour of the hair. Besides these substances, hair contains silex, carbonate and phosphate of lime, and oxides of iron and manganese.

WOOL is merely a finer hair. It has scarcely been chemically examined, but it has one of the characteristic properties of indurated albumen, that of forming a saponaceous compound with alkalis.

SILK is connected with these substances in physical properties and chemical constitution, though it has also some peculiarities. It is in fine fibres, of different shades of co-



lour, naturally covered with a kind of varnish which communicates stiffness and elasticity : both the colouring matter and varnish are removed by the successive application of weak alkaline leys, alcohol and diluted muriatic acid. The pure silk is insoluble in water, even at a boiling heat, and in alcohol ; but is dissolved by acids, and also by the fixed alkalis, with an exhalation of ammonia. Nitric acid disengages nitrogen gas, and forms prussic and oxalic acids, with a portion of a peculiar bitter matter, which appears to be the same product with the yellow bitter acid produced in the decomposition of fibrin by nitric acid.

The silk-worm forms along with the silk an acid liquor, which was supposed to be a peculiar acid, and received the name of Bombic acid ; it appears to be merely acetic acid, weak and impure. Some other acids secreted by insects are of a similar nature ; that secreted by the ant, however, Formic acid, as it has been named, appears to be a distinct compound. It had been affirmed to be a mixture of acetic and malic acids ; but Gehlen has stated, that its smell and taste are peculiar, that it has a greater specific gravity, and a greater saturating power, than acetic acid, and forms different salts. Berzelius also considers it to be a distinct acid, composed, according to his analysis, of two atoms of carbon, 12, three of oxygen, 24, and one of hydrogen, 1, = 37. It would from this appear to approach very closely in nature to oxalic acid, containing only an additional atom of hydrogen. Dobereiner has stated, that it is resolved by the action of strong sulphuric acid into carbonic oxide and water. He has also succeeded in forming this acid artificially, by gently heating a solution of tartaric acid, and bitartrate of potash, with black oxide of manganese.



SECT. X.—*Of Bone and Shell.*

BONE and Shell differ from the preceding substances in their greater induration, derived from the larger quantity of earthy matter that enter into their composition. In bone the earthy matter is principally phosphate of lime, in shell it is carbonate of lime, but these are intermixed in the different varieties; and there are intermediate substances, the crustaceous coverings of certain marine animals, and of zoophytes, in which the proportions of phosphate and carbonate are nearly equal.

Bone admits of a simple analysis, by which its immediate principles are discovered. By boiling in water, a liquor is formed, which becomes of the consistence of a jelly on cooling, proving the presence of a large proportion of gelatin. If the bone, without boiling in water, be digested in dilute muriatic or nitric acid, the gelatin and earthy matter are dissolved, and a transparent cartilaginous substance remains, retaining the figure of the bone. By calcination in the open fire, the animal matter is burnt out, and the earthy matter is obtained, which farther analysis discovers to be phosphate of lime; it is likewise separated during decoction under increased pressure, an experiment which proves that it pre-exists in the bone, and is not formed during the calcination. Lastly, during the boiling in water, a portion of oily matter separates, and collects on the surface. By these experiments, then, bone is proved to be composed of gelatin, cartilage, phosphate of lime, and fatty matter, the last being probably adventitious, and derived from the marrow diffused through the layers of bone. Some other principles appear to be present, too, in smaller proportion. A little carbonate of lime exists in recent bone; and a larger



quantity, with a portion of sulphate of lime, are found in calcined bone, the greater part of which is probably formed during the calcination. Berzelius discovered fluuate of lime, and phosphate of magnesia. According to his analysis, 100 parts of human bones consist of animal matter 33.3, phosphate of lime 51.04, carbonate of lime 11.3, fluuate of lime 2, phosphate of magnesia 1.16, and soda, muriate of soda, and water, 1.2. Traces of silex, argil, manganese and iron have also been discovered in bone. The proportions of all these ingredients must be various in bones in different states; the earthy matter becomes more abundant as the animal advances in life.

When bone is exposed to heat gradually raised, it is decomposed, a large quantity of carbonate of ammonia is volatilized, formed by new combinations of the elements of the animal matter. This is accompanied with a portion of fetid oil, and quantities of prussic and sebacic acids, carburetted and sulphuretted hydrogen gases. The bone remains charred, but when urged with a strong heat in an open fire, becomes white; this residual matter, which retains the figure of the lime, being composed of its earthy salts.

Bone is little liable to spontaneous decomposition, the reaction of the elements of its animal matter being prevented by the earthy matter in which it is involved, and the solidity which this communicates. In fossil bones which have been long buried in the earth, the animal matter is removed by slow decomposition, and replaced by carbonate of lime, conveyed by infiltration.

The ENAMEL of the teeth is evidently of the nature of bone. It has the peculiarity, however, of containing a very small proportion of animal matter. In dissolving in acids, it produces a slight effervescence, and contains therefore a portion of carbonate mixed with its phosphate



of lime. Morichini discovered fluoric acid in the enamel, vapours of it being disengaged by the action of sulphuric acid, and also in ivory, or the enamel or outer layer of the fossil-teeth of the elephant.

SHELL, or the hard covering with which the bodies of many marine and of a number of land animals are covered, differs from bone in containing chiefly carbonate of lime, with which are sometimes mixed small proportions of phosphate of lime. Marine shells are of two descriptions, either of a porcellanous aspect, with an enamelled surface and fibrous texture, or composed of the substance called Nacre, or Mother of Pearl. The former consist of carbonate of lime with a small proportion of indurated albumen. The latter contain the animal matter in much larger proportion; it constitutes a large part of the shell, and is so highly indurated as not to be gelatinous; it appears to be deposited in layers, alternating with thin layers of carbonate of lime. Mother of pearl, and pearl itself, are of this structure and composition; and their waved appearance, and iridescence, and nebulous semi-transparency, appear to arise from it. The substance of zoophytes, comprising the varieties of madrepor, millepore, and tubipore, consists of carbonate of lime, with animal membrane. The covering of crustaceous marine animals, and the shells of the eggs of birds, contain both phosphate and carbonate of lime, and are thus intermediate between Bone and Shell.

#### SECT. XI.—*Of Fat, Spermaceti, Sebacic Acid.*

ANIMAL fat has nearly the same properties as vegetable oil. In the living animal body it is nearly fluid, and is contained in distinct cells; after death it in the greater



number of cases becomes concrete, and more or less firm. It is freed from the membranous matter by melting it, a little water being added to prevent the heat from rising too high. As thus obtained, it is insipid and inodorous; when of a soft consistence it forms Axunge or Lard; when firmer, Tallow. From some animals, as from the whale and other marine animals, it is obtained fluid, forming Animal Oil.

Fat is insoluble in water or in alcohol. Exposed to the air it is liable to become rancid, a change connected with the absorption of oxygen. It melts easily at  $90^{\circ}$  or  $100^{\circ}$ ; by raising the heat it is rendered more acrid, and exhales a pungent vapour; in close vessels it is decomposed, and among other products yields a large quantity of olefiant gas. Fat is inflammable, and affords by combustion water and carbonic acid. Like the vegetable oils it appears to be composed of carbon, oxygen and hydrogen. The acids act chemically on fat. Sulphuric acid chars it. Nitric acid mixed with it in small quantity gives it a firmer consistence, and renders it soluble in alcohol; in this state it has been termed Oxygenated Fat. The alkalis combine with fat, and form with it perfect soaps. It forms saponaceous compounds with some of the earths, and unites with metallic oxides. It even facilitates the oxidation of some of the metals, as copper and quicksilver, by the atmospheric air.

The acid obtained in the distillation of fat was regarded as a peculiar one, and received the name of SEBACIC ACID. It was said to be procured by heating fat with lime, and afterwards adding sulphuric acid; but the product thus formed has been shown to be merely acetic acid, intermixed with sulphurous acid. The proper sebatic acid is obtained by distilling fat, treating the product, which contains sebatic and acetic acids, with hot



water, and adding to the filtered liquor acetate of lead; the precipitated sebate of lead is heated with sulphuric acid, when an unctuous substance collects on the surface, soluble in water when boiled with it, and which, on the water cooling, is deposited in crystalline needles. This is the sebacic acid; its taste is slightly sour, it reddens litmus, is soluble in water and in alcohol, and melts at a moderate heat: with the alkalis and earths it forms soluble salts. Berzelius, however, considers it to be merely impure benzoic acid.

A peculiar view of the nature of fat has been given by Chevreul and Braconnot. They consider it to be not a homogeneous substance, but to consist of two different principles, Stearin and Elain, as Chevreul has named them; the former, of a firm consistence, resembling suet or tallow, the other, more soft or liquid, analogous to vegetable oils. They may be separated by submitting fat to the action of boiling alcohol: on allowing the liquor to cool, the stearin is deposited in white acicular crystals, which are purified by being again dissolved in alcohol; the elain is procured by evaporating the alcoholic solution. Braconnot obtained these principles by a simpler process; pressing any oily or fatty substance between folds of bibulous paper, the oily matter or elain is absorbed, while the stearin remains untouched.

STEARIN is of a pure white colour, inodorous, and insipid, bearing much resemblance to wax. It melts at  $110^{\circ}$  or  $120^{\circ}$ , and in cooling crystallizes in fine needles; it forms soap with the alkalis. It dissolves sparingly in alcohol; by the action of acids and alkalis it is converted into a substance analogous to spermaceti, and into an oil, both soluble in alcohol.

ELAIN obtained from its solution in alcohol is, when pure, a colourless fluid, lighter than water; it is readily



soluble in alcohol, and forms soaps with alkalis. It may be used with advantage for lessening the friction in delicate machinery, as in watches, since it suffers no change from exposure to the air, and remains liquid even at  $32^{\circ}$ . Braconnot supposes all fatty substances, both animal and vegetable, to be compounds of these two principles in various proportions, and in no product is either of them pure.

When fatty substances are converted into soaps by combination with alkalis, these two principles are decomposed and converted into two others, having acid properties, called by Chevreul, Margaric and Oleic acids, which combine with the alkali employed.

MARGARIC ACID is obtained by submitting the soap formed by the action of potash on hogs-lard to the action of boiling water; the solution, on cooling, deposits a pearly matter, which is the margarate of potash; the oleate of potash remains in solution. The pearly matter is dissolved repeatedly in boiling water; it is then washed with alcohol, and lastly decomposed by muriatic acid; the margaric acid being insoluble, is separated. It is of a white colour and pearly lustre, whence its name, (from *μαργαριτης*, a pearl); it is insipid, lighter than water, melts at  $135^{\circ}$ , and on cooling crystallizes in brilliant white needles; by a higher heat it is volatilized and decomposed; it is soluble in heated alcohol. It reddens litmus, and combines with the alkalis; its salts are of sparing solubility; the margarate of potash consists of 100 of acid, and 8.8 of base; the bi-margarate of 100 and 17.7 of base.

OLEIC ACID remains in solution with potash in the preceding process. To obtain it, the oleate of potash is decomposed by tartaric acid, again combined with potash, and again decomposed by tartaric acid. An oily-like fluid, much lighter than water, rises to the top, which is



the oleic acid ; at  $35^{\circ}$  it congeals into crystalline needles ; it is insoluble in water, soluble in alcohol, reddens litmus, and combines with the different salifiable bases, forming compounds somewhat analogous to soaps. Besides these two products, a sweet substance is produced in the saponification of fat, which was formerly called the Sweet principle of oils, but has been termed Glycerine.

A remarkable circumstance relative to fat is its artificial formation, which is said to have been effected by Dobereiner and by Berard. The latter produced a substance similar to fat, by passing a mixture of one measure of carbonic acid, ten measures of carburetted hydrogen, and twenty of hydrogen, through a red hot tube ; small white crystals were formed, lighter than water, insoluble in that fluid, soluble in alcohol, and which when heated melted into an oil. Dobereiner, by employing a mixture of watery vapour and coal gas, procured an analogous product.

The fluid species of fat are principally the whale oil and the spermaceti oil. The former is melted out of the blubber of the whale by the application of heat, and is used for burning in lamps, and for affording oil gas. It has generally a strong smell, and a yellowish colour from impurity ; but when procured by a gentle heat is pale and limpid : it boils at  $640^{\circ}$ . From its analysis by Dr Thomson, it is inferred to consist of twelve atoms of carbon, 72, two of oxygen, 16, and seventeen of hydrogen, 17, = 105. The spermaceti oil is extracted by pressure from an oily matter found in the head of the *Physeter macrocephalus* or spermaceti whale. It is much purer than whale oil, and better adapted for burning in lamps, as it leaves no residuum to clog the wick. It would appear, from Dr Ure's analysis, to be composed of ten atoms of carbon, 60, one of oxygen, 8, and nine of hydrogen, 9, = 77.



SPERMACETI, or Cetine, as it has been called by Chevreul, is the substance left after the expression of the oil, from the matter found in the head of the spermaceti whale. It resembles wax rather than fat, but is more fusible, melting at  $113^{\circ}$ ; it is readily dissolved by warm ether and oil of turpentine, and sparingly by alcohol. It is of a flaky texture, soft and brittle, white and brilliant; it is insoluble in water; it burns with a clear flame; the alkalis form with it soaps less perfect than those with fat, and much less soluble.

ADIPOCIRE. It has already been mentioned, that the flesh or muscular fibre of animals is susceptible, in certain circumstances, of a singular change, being converted into a substance resembling fat or spermaceti. This has been named Adipocire, as intermediate between wax and fat. To effect this change, muscular fibre is exposed to the continued action of running water for several months; or it has happened in the bodies of the dead buried in moist earth, as was first particularly remarked on the removal of a burying ground in Paris. It may be accomplished more quickly by digesting the flesh in strong nitric acid. Adipocire melts when heated above  $90^{\circ}$ ; it has a light yellow colour, is unctuous like tallow, is dissolved by heated alcohol and ether, but is deposited when they cool. It forms a soap with the fixed alkalis, but not with ammonia. It has been the general opinion that the flesh is really converted, by a new arrangement of its elements, into adipocire; but Gay-Lussac and Chevreul suppose that it is merely separated by the destruction of the fibrin; and Chevreul regards it as a compound of margaric acid with ammonia produced in this decomposition. Dr Thomson considers the original opinion the more probable one.



SECT. XII.—*Of the Cerebral Pulp.*

THE soft pulpy matter which forms the substance of the brain and spinal marrow has been submitted to chemical examination by Vauquelin, and the results prove it to contain various substances, some of a very peculiar nature. It speedily suffers decomposition when exposed to the air; but immersed under water, may be preserved without much change. From containing albumen, it is coagulated by a gentle heat, also by acids, alcohol, and various metallic salts. It forms a saponaceous compound with alkalis, owing to a portion of osmazome and fatty matter existing in it. Boiling alcohol dissolves these principles, becoming of a green colour. The cerebral pulp is decomposed by heat, and, when dry, inflames if the air is admitted, and in its combustion produces a considerable quantity of sulphurous acid. According to its analysis by Vauquelin, 100 parts of it are composed of water, 80, albumen, 7, white fatty matter, 4.53, red fatty matter having a strong odour like that of the brain, 0.7, osmazome, 1.12, uncombined phosphorus, 1.5, free sulphur and salts, principally phosphates of potash, lime, and magnesia, and muriate of soda, 5.15.

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CHAP. III.—OF THE DECOMPOSITION OF ANIMAL SUBSTANCES FROM THE REACTION OF THEIR ELEMENTS.

THE elements of which animal matter is composed having mutual affinities, and these being nicely adjusted in the combinations which constitute its varieties, they are



liable to be altered by slight changes of circumstances ; hence the character eminently distinctive of the animal products—their extreme susceptibility of decomposition. The results of the changes which they suffer from the new combinations into which their elements enter, are different, as these are established at a natural temperature, or by the application of heat ; and these two species of decomposition require therefore to be considered apart.

SECT. I.—*Of the Decomposition of Animal Substances at a high temperature.*

THE general result of the decomposition of animal substances by heat, is the transition of their elements into binary combinations. From the union of portions of their nitrogen and hydrogen, ammonia is formed ; carbon combining with oxygen forms carbonic acid, and frequently carbonic oxide ; and with the addition of hydrogen, empyreumatic acid ; the combination of carbon with hydrogen gives rise to the formation of empyreumatic oil, and of carburetted hydrogen ; sulphur and phosphorus are partly disengaged in combination with hydrogen, and partly remain united with oxygen, forming sulphuric and phosphoric acids, combined with the alkalis or earths of the animal matter. The proportions of these products are necessarily very variable.

A product is obtained in many of these cases of decomposition,—Prussic acid, the chemical history of which remains to be delivered. Its existence as a product of vegetation has been already noticed, but it is usually by the decomposition of animal matter that it is obtained.

It enters along with peroxide of iron into the composition of the blue pigment known by the name of Prussian Blue. This substance is prepared by calcining dried



blood at a red heat, with the potash of commerce, lixiviating the residual matter with successive portions of boiling water, and adding to the ley, reduced by evaporation, a solution of one part of sulphate of iron, and a solution of two parts of common alum. A precipitate is thrown down of a greenish colour, which assumes a very rich blue when washed with a little diluted muriatic acid, and forms the Prussian Blue of commerce. The acid existing in this substance was discovered, by Scheele, in 1782, was shown by Berthollet to consist of carbon, nitrogen, and hydrogen; but was first obtained in a pure state, and its composition fully ascertained, by Gay-Lussac, in 1815. The latter distinguished chemist has proved, that it consists of a compound radical, consisting of carbon and nitrogen, before alluded to, (vol. i. p. 634,) which he named Cyanogen, and which, in prussic acid, is acidified by hydrogen, as chlorine forms muriatic acid with hydrogen, and that its salts, when dried, are not prussiates, but cyanides, analogous to chlorides and iodides. From this constitution, he has proposed to alter the name of Prussic, to that of Hydrocyanic acid, and the latter appellation is often employed. The original, however, appears to be the preferable name. The history of the acid will first be given, and then that of its compound radical.

To obtain Prussic acid, the first step is, to prepare what used to be called Prussiate of mercury. This is done by boiling the red peroxide of mercury in fine powder with twice its weight of prussian blue in water; the blue colour disappears, and a quantity of the red oxide of iron is precipitated; on filtering and evaporating the solution, the prussiate, or, as it is now named, the Cyanide of mercury, crystallizes in four-sided prisms, obliquely truncated. These are dried at a moderate temperature,



and heated with two-thirds of their weight of muriatic acid, in a glass retort, to which a wide glass tube, placed horizontally, is attached. In this tube are placed fragments of marble, and beyond them fused chloride of calcium, and it ends in a receiver surrounded by ice. Prussic acid vapour is evolved on the application of heat with muriatic acid and watery vapour; the two latter products are abstracted by the substances in the tube, and the prussic acid is condensed in the receiver.

An easier process has been given by Vauquelin, which also yields a larger quantity of the acid. It consists in passing sulphuretted hydrogen through a tube filled with dry cyanide of mercury; black sulphuret of mercury and prussic acid are immediately produced, and by a gentle heat, the latter is made to pass forwards to a cool receiver. To prevent intermixture of sulphuretted hydrogen, a quantity of carbonate of lead is placed near the extremity of the tube.

Prussic acid, thus produced, is a limpid colourless fluid; it has a peculiar odour, resembling that of peach blossom, or bitter almonds, which indeed owe their smell and narcotic powers to the presence of this acid. Its specific gravity at  $45^{\circ}$  is 0.7058; its taste is at first cool, but soon becomes acrid and irritating. It is a rapid and powerful narcotic poison; a few drops of it, in its concentrated state, given to small animals, destroy life; a single drop even, applied to the tongue of a rabbit, or a dog, causes instant death; the same effect is produced by applying a vessel containing it to the nostrils; and a German chemist is said to have lost his life, from a quantity of it having been dropt on the naked arm. Its vapour, though largely diluted with air, produces headache and giddiness; hence it has been recommended not to prepare it in warm weather in a close room. It is an exceedingly volatile liquid, much



more so even than ether; it boils at  $79^{\circ}$ , and evaporates so rapidly at lower temperatures, that it cannot be poured from one vessel to another, without a great part of it being lost. Its vapour may be, in warm weather, collected over mercury, and at  $68^{\circ}$  supports a column of 15 inches of that fluid; introduced into any gas, it increases the volume five fold. Though so volatile, it is congealed by a cold not very intense, becoming solid and crystalline at zero; from these two characters arises a singular phenomenon, that if a drop of it be allowed to fall on glass, or a bit of paper, it instantly freezes from the cold produced by its own evaporation,—a change exhibited by no other fluid.

Prussic acid reddens vegetable colours but faintly, and from its solubility the effect is evanescent. It unites with water and alcohol in every proportion. It combines with the alkalis and earths, forming salts, called Prussiates, or Hydrocyanates; these compounds have little permanence; the alkaline powers of the bases are not neutralized, though a large excess of the acid is added; so weak is the acidity of this substance, that its salts are decomposed even by so feeble an acid as the carbonic. They are poisonous, and have the odour of prussic acid. The best known of them is the prussiate of potash; this may be formed, by mixing the liquid acid with solution of potash; it can also be obtained, by calcining what is named the triple prussiate, or ferro-prussiate or ferro-cyanate of potash, by a continued red heat, which separates the iron; a cyanide of potassium remains, which, when thrown into water, becomes a prussiate of potash, the cyanogen uniting with the hydrogen of the water, and the potassium with the oxygen: The first process, however, is the more certain one. Solution of prussiate of potash is alkaline to the taste, and changes vegetable colours to green. With salts contain-



ing protoxide of iron, it gives a yellow precipitate, and with those containing the peroxide, a light blue precipitate, both of which become of a deep blue, on exposure to the air. The salt exists only in solution, being converted, when thoroughly dried, into cyanide of potassium. Prussiate of ammonia crystallizes in small prisms; it is so volatile, that its vapour supports, at  $72^{\circ}$ , a column of 15 inches of mercury, and at  $97^{\circ}$  is equal to the pressure of the atmosphere. Dr Thomson states, that when prussian blue is exposed to a red heat in a copper tube, crystals of this salt are obtained.

Prussic acid is very liable to spontaneous change. When concentrated, it in a few hours, though excluded from air or moisture, becomes of a brown colour; a dark precipitate containing carbon and nitrogen falls, and ammonia is formed, which unites with the remaining acid. These changes do not happen so readily when the acid is diluted.

Prussic acid, from its powerful action on the living system, has been employed medicinally, particularly in consumption; it is given in the state of a dilute aqueous solution, which may be prepared, by dissolving cyanide of mercury in a quantity of water, (as a drachm in an ounce of water,) and passing sulphuretted hydrogen through the solution; the cyanide is decomposed, and prussic acid remains dissolved. Or the process followed at Apothecaries' Hall, London, may be employed, in which a pound of cyanide of mercury, six pints of water, and one of muriatic acid, are mixed together, and six pints distilled off; this solution has a specific gravity of 0.995; it should be kept excluded from the light, though even then it slowly changes. The proportion of acid in it may be estimated in the manner proposed by Dr Ure, by finding the quantity of red oxide of mercury which it will dissolve.



The vapour of prussic acid is inflammable, and it forms with oxygen gas an explosive mixture, which is kindled by the electric spark ; in the combustion, nitrogen, water, and carbonic acid are produced. Subjected to galvanic influence the acid is decomposed ; its hydrogen passes to the negative pole, and the cyanogen to the positive pole. Transmitted through a red hot tube, it is partially decomposed, charcoal being deposited, and nitrogen, hydrogen, and cyanogen disengaged. But the most simple and decisive result as to the composition of prussic acid was obtained by Gay-Lussac, by heating potassium in it ; a cyanide of potassium was formed, and hydrogen equal to half of the original volume remained : it was hence inferred that prussic acid consists of equal volumes of hydrogen and cyanogen united without condensation.

**CYANOGEN.**—To obtain this interesting substance, pure cyanide of mercury is prepared, by digesting prussian blue in dilute muriatic acid, which removes the alumina and subsulphate of iron present in that substance, and then boiling this purified ferro-prussiate of iron with red oxide of mercury, and evaporating the clear solution. The cyanide of mercury thus formed is cautiously dried and exposed to a low red heat in a small glass retort ; it melts, blackens from the liberation of a portion of charcoal, and is resolved into metallic mercury, which is volatilized, and cyanogen gas. The latter may be collected over mercury. It is permanently elastic under ordinary pressures. By generating it in close tubes, however, Mr Faraday reduced it to the liquid form ; it was a colourless and very limpid fluid, which suffered no change at  $0^{\circ}$  ; it appeared to be lighter than water ; when the tubes were opened it resumed the gaseous form, producing considerable cold in its evaporation ; the pressure of



its vapour was found not to exceed  $3\frac{1}{2}$  atmospheres. Cyanogen gas has a strong and penetrating smell; and its solution in water has a very sharp taste. It is inflammable, burning when kindled with a bluish purple flame; it bears a high temperature, however, without decomposition. Water absorbs four times and a half its volume of it, alcohol 23 times its volume; the former solution reddens litmus, but this is from the cyanogen and water reacting on each other; on applying heat the gas is disengaged with a portion of carbonic acid gas, and the blue colour of the litmus returns.

If one volume of cyanogen gas be mixed with two of oxygen gas, and the electric spark passed through the mixture, explosion happens, and there result two measures of carbonic acid gas and one of nitrogen, without any production of water. Hence it appears that cyanogen is composed of one volume of nitrogen, and two of carbon vapour condensed into one volume, or by weight, of one atom of nitrogen, 14, and two of carbon, 12; it is therefore a bi-carburet of nitrogen, and its equivalent is 26. If to this we add one atom of hydrogen, 1, we obtain 27, the equivalent of prussic acid. The specific gravities of the two compounds, in the elastic state, agree with this view of their constitution. That of cyanogen should be equal to,  $0.9722$  the density of nitrogen gas added to  $0.833$ , twice the density of carbon vapour, or to  $1.8055$ , which corresponds closely with the number determined by experiment. Again, if  $0.0694$ , the density of hydrogen gas, be added to this, and the product divided by two, (the elements of prussic acid suffering no condensation,) the result  $0.93749$  will be found to differ very little from the density of prussic acid vapour, as experimentally ascertained.

The affinities exerted by cyanogen are not powerful.



Phosphorus, sulphur and iodine may be volatilized in it unchanged; but the last of these, and it is said also the former, form compounds with it, when heated with cyanide of mercury. It combines with a number of metallic bodies. When potassium is heated in it, that metal becomes red hot, and a cyanide of potassium is formed; this when thrown into water is converted into a prussiate of potash. Various other cyanides may be obtained by combining bases in solution with prussic acid and drying the compounds, when the oxygen of the base, and the hydrogen of the acid, form water, and a metallic cyanide remains. The most important of these is the cyanide of mercury, the mode of preparation of which has been already noticed; it is colourless and inodorous, has a very unpleasant metallic taste, and is highly poisonous; it is supposed to dissolve unchanged in water, as the solution has no odour of prussic acid, and the addition of alkalis does not precipitate oxide of mercury; it is a bi-cyanide, consisting of one atom of mercury, 200, and two of cyanogen, 52, = 252. The colouring matter of prussian blue was at first conceived by Gay-Lussac to be cyanide of iron, and it was from the supposed power of producing this colour that he gave to cyanogen its name, (from *χρᾶνος*, *blue*, and *γεννομαι*, *to generate*); but it is now proved, as will immediately be explained, that this colouring matter is of a more complicated nature. The combinations of this radical with oxygen, chlorine, iodine, sulphur, and its anomalous union with iron, may now be noticed.

**CYANIC ACID.** When cyanogen gas is transmitted through an alkaline solution, a considerable quantity of it is absorbed. It was supposed by Gay-Lussac that the cyanogen united with the alkalis, though the compounds could not be obtained dry. But it is now believed, from



the experiments of M. Wohler, that prussiate and cyanate of potash are formed by decomposition of the water, in the same way that muriate and chlorate of potash are produced when chlorine is absorbed by solution of potash. The cyanate of potash is obtained more easily and unmixed with prussiate, by exposing to a low red heat a mixture of equal weights of the dried ferro-prussiate of potash and peroxide of manganese, and boiling the calcined mass in alcohol; on cooling, small tabular crystals of cyanate of potash form like those of chlorate of potash. In this process, it may be conjectured, that the salt is converted by the heat into a ferro-cyanide of potassium, losing both its hydrogen and oxygen; that this receives oxygen from the metallic peroxide, and the cyanate of potash is separated from the oxides of iron and manganese by the alcohol. Cyanic acid may be transferred from the potash to other bases by double affinity; the cyanate of barytes is soluble, those of lead, mercury, and silver insoluble. Wohler infers this acid to consist of one atom of cyanogen, 26, and one of oxygen, 8, = 34, or of two atoms of carbon, 12, one of oxygen, 8, and one of nitrogen, 14. This, it may be remarked, is the same with the constitution assigned to the fulminic acid by Gay-Lussac, (vol. ii. p. 162.) which has been attempted to be explained by the supposition, that bodies may unite in the same proportions, and yet, from their particles being arranged in a different manner, may form totally different compounds. Such an opinion, however, cannot be admitted without more certain evidence than we possess. Cyanic acid is very easily decomposed, so that it cannot be obtained uncombined; it is not, however, like the fulminic acid, decomposed with explosion. A remarkable fact with regard to it, is the facility with which it is resolved by water into carbonic acid and ammonia. If the solution



of cyanate of potash be merely heated this change happens, and still more readily if a diluted acid is added. This effect may easily be explained by conceiving each atom of the cyanic acid to unite with three atoms of water; it consists, as has been stated, of two atoms of carbon, one of oxygen, and one of nitrogen; if to these we add three atoms of oxygen and three of hydrogen, we obtain two atoms of carbonic acid and one of ammonia.

**CHLORO-CYANIC ACID.** Berthollet observed, that when chlorine gas is transmitted through a solution of prussic acid, it no longer forms a blue precipitate with oxide of iron, and its other properties are also changed: supposing that oxygen had been communicated to it, he called it Oxy-prussic acid. Gay-Lussac, regarding it as a compound of chlorine and cyanogen in equal volumes, has termed it Chloro-cyanic acid. It may be separated from the muriatic acid by agitation with oxide of mercury, and on applying heat to the solution, rises in the elastic form. It is not pure, however, being always mixed with carbonic acid, produced by reaction between its elements. Chloro-cyanic gas is colourless, and has a very strong pungent smell; it reddens litmus, is not inflammable, and does not detonate with oxygen. Its aqueous solution does not precipitate nitrate of silver nor barytic water. The alkalis absorb it rapidly, and an excess of them is necessary to destroy its odour. On adding an acid to these compounds, a strong effervescence of carbonic acid is produced, and ammonia and muriatic acid remain. Chloro-cyanic acid is inferred by Gay-Lussac to consist of one atom of chlorine, 36, and one of cyanogen, 26, = <sup>62</sup>~~62~~; its 62 specific gravity in the elastic form should be 2.1257.

**CYANIDE OF IODINE**, discovered by M. Serullas in



1824, is formed by mixing two parts of iodine and one of cyanide of mercury, both dry, and heating them in a wide-mouthed bottle, placed under a glass jar. White fumes soon appear, which condense on the sides of the jar in white flakes like cotton. This is the cyanide of iodine. It forms white acicular crystals, has a caustic taste, and a pungent odour; it is volatile, and its vapour irritates the eyes; it sinks in sulphuric acid; it is soluble in water and in alcohol; its solutions give no indication of acidity. Thrown into liquid potash, hydriodate and prussiate of potash are formed; the solution gives a rich green precipitate with proto-sulphate of iron. Sulphurous acid immediately resolves cyanide of iodine, when water is present, into prussic acid and iodine. M. Serullas conceives it to consist of one atom of cyanogen, 26, and one of iodine, 124, = 150.

SULPHO-CYANIC ACID was discovered by Mr Porret, who showed it to consist of carbon, nitrogen, sulphur, and hydrogen. He gave to it the name of Sulphuretted Chyazic acid, the term Chyazic being derived from the first letters of three of its elements, carbon, hydrogen, and azote, with the usual termination, indicating acidity. The appellation of Sulpho-cyanic acid now applied to it is incorrect, as it contains hydrogen; that of Sulpho-prussic acid would be preferable, but the other is commonly employed. To obtain it, equal weights of the triple prussiate or ferro-prussiate of potash and sulphur are heated together for some time; the mass when cold is reduced to powder, and diffused in water; sulpho-cyanate of potash exists in this solution, which being freed from any iron that may adhere to it by the addition of liquid potash, is to be decomposed by sulphuric acid, and the solution distilled; sulpho-cyanic acid mixed with water will be condensed



in the receiver, while sulphate of potash remains in the retort.

The solution of this acid is colourless, or has a slight pinkish hue; its odour resembles that of acetic acid. In the most concentrated state in which Mr Porret obtained it, its specific gravity was 1.022. At the temperature of about  $54^{\circ}$  it crystallizes in six-sided prisms; it boils at about  $216^{\circ}$ . Passed over red hot filings, it is decomposed, sulphuret of iron being formed, and prussic acid and sulphuretted hydrogen disengaged. By the action of chlorine and iodine on its solution, it is converted into sulphuric and prussic acids. From its analysis, it appears to consist of one atom of cyanogen, 26, two of sulphur, 32, and one of hydrogen, 1; hence its equivalent is 59.

Sulpho-cyanic acid has distinctly acid properties. It reddens litmus, and combines with bases. The salts it forms with the alkalis are supposed to exist only in solution, the hydrogen of the acid and the oxygen of the base being conceived to unite when the salts are dried, and to escape in the state of water, so that a metallic sulpho-cyanuret remains; thus, sulpho-cyanate of potash, when dried, is conceived to be a sulpho-cyanuret of potassium. This substance forms crystals somewhat similar to those of nitre; they are deliquescent, fusible, have a cool taste, and are readily soluble in water, forming a neutral solution. With some bases, the acid forms salts, which remain as such when dry; thus it forms an insoluble white salt with protoxide of copper. With peroxide of iron, it produces a soluble salt of a deep blood-red colour; hence the per-salts of iron are the best tests of the presence of sulpho-cyanic acid.

FERRO-PRUSSIC ACID, or FERRO-CYANIC ACID, as it is



frequently called, is the most important of the combinations of Cyanogen; its nature is as yet, however, more obscure than that of any compound of this substance which has been hitherto noticed. By boiling potash with prussian blue, a neutral salt is obtained, containing the alkali with prussic acid. But besides these it always contains a quantity of protoxide of iron, which cannot be separated from it by any reagent; and it is found, that when this salt in solution is mixed with solutions of metallic salts, precipitates fall, which likewise always contain protoxide of iron. It is hence concluded, that a powerful affinity exists between prussic acid and protoxide of iron, and that from this cause a number of triple compounds are formed, consisting of the acid, the oxide of iron, and some other base; thus, the salt that has been mentioned is called a triple prussiate of potash and protoxide of iron. A very different view, however, of the composition of these substances was taken by Mr Porret, and which has been embraced by a number of chemists. On submitting the triple prussiate of soda and protoxide of iron to the action of galvanism, instead of the two bases being attracted to the negative pole, while the prussic acid passed to the positive side, the soda alone appeared at the negative side, and the oxide of iron and prussic acid passed together to the positive pole. From this phenomenon he drew the inference, that the oxide of iron is really an element of the acid, not a base with which it is combined, and that this Ferro-Prussic acid, or Ferrureted Chyazic acid as he named it, combines with alkalis and metallic oxides, exactly as a binary acid would unite with them, and forms the salts which have been called triple prussiates. In prosecuting his researches, he procured this Ferro-Prussic acid in an insulated state, and showed its properties to be peculiar. The method by which he obtained it consisted



in dissolving the ferro-prussiate, or triple prussiate of barytes in water, and adding to it a sufficient quantity of sulphuric acid to precipitate all the barytes; the liquor is then a solution of pure ferro-prussic acid. Or it may be procured in a crystallized state, by dissolving 50 grains of the triple prussiate of potash in a little warm water, and adding to it a solution of 58 grains of crystallized tartaric acid in alcohol; bitartrate of potash is precipitated, and the solution, by spontaneous evaporation, yields ferro-prussic acid in small yellow crystals.

Ferro-prussic acid in solution has a pale lemon yellow colour, has no odour, and is not poisonous in small quantities. It is decomposed by a gentle heat, or by exposure to a strong light, prussic acid and white ferro-prussiate of iron being formed, the latter of which, by absorbing oxygen, becomes prussian blue. It unites with the alkalis, earths, and metallic oxides, forming the salts which have long been termed triple prussiates. It exhibits the acid properties more distinctly than the prussic acid, reddening litmus, neutralizing alkaline qualities completely, and separating the carbonic and acetic acids from their combinations. It has so powerful an attraction to peroxide of iron, that it takes it even from the more powerful acids, as the sulphuric. The crystals of this acid, on exposure to light, become covered with a crust of prussian blue, from part of the iron passing to the state of peroxide, and uniting with the undecomposed portion of acid. It thus appears, that the balance of affinities is in this acid apt to be subverted, and that new arrangements of the elements are easily induced.

Mr Porret inferred, from his first experiments on this acid, as has been stated, that its elements were oxide of iron and prussic acid. From later researches, however, he has concluded that the iron is not even in the state of



oxide, but that the real acid is composed of one atom of metallic iron, one atom of prussic acid, and two atoms of carbon. This view has been farther altered by Robiquet, who affirms that ferro-cyanic acid consists of one atom of cyanide of iron united with two atoms of prussic acid, or of two atoms of hydrogen, 2, one of iron, 28, and three of cyanogen,  $\frac{76}{32} = \frac{106}{32}$ ; or it is a hydracid, consisting of a radical not yet obtained in an insulated state, composed of three atoms of cyanogen and one of iron, and acidified by one atom of hydrogen. Hence, when ferro-prussic acid enters into combination with a base, it is conceived to be decomposed like muriatic acid; its hydrogen unites with the oxygen of the base, and a ferro-cyanide of the metallic radical of the base remains; when ferro-prussiate of potash, for instance, is thoroughly dried by a high temperature, it is supposed to become a ferro-cyanide of potassium.

In opposition to these opinions, the view is still maintained by many, particularly by Berzelius, that no such acid as that called the ferro-prussic or ferro-cyanic exists, and that the salts called triple prussiates consist merely of the super-prussiate of protoxide of iron in union with other bases. With regard to the comparative merits of these doctrines, it does not appear that any decisive evidence has yet been brought forward in support of Mr Porret's opinions. It may be said, indeed, that they give a satisfactory explanation of the fact of iron existing in the triple prussiates, and yet not being detected by sulphuretted hydrogen, and other tests; for these tests indicate only the presence of oxide of iron, not of iron in the metallic state, in which it is supposed to exist in ferro-cyanic acid; and the effect produced by galvanism is also considered to be highly favourable to these opinions. It is equally possible, however, that the former circumstance



may be owing to the strong affinity between prussic acid and oxide of iron, and the result of the galvanic experiment does not appear to afford an argument of much weight. It is not easy to conceive, on Mr Porret's view, how metallic iron should produce, in any combination, a more powerful acidity; but on the older theory of the salts being simply triple prussiates, the explanation is obvious and probable, that the protoxide of iron, by its attraction to the prussic acid, counteracts its volatility, and its tendency to decomposition, and thus, by rendering it more permanent, adds to its power. The instance of alum, which is a more definite, permanent, and neutral combination than sulphate of alumina, shows how the agency of one base may, by its affinity to an acid, bring that acid into more permanent and definite union with another base, than what the acid would alone be disposed to form. Another instance is that of the bi-tartrate of potash, which is found in many cases, as has been stated, (p. 510.) to act as a free acid, and even to combine with bases on which tartaric acid itself exerts no action. The siliceo-fluoric acid is an example still more similar, in which a portion of a base accompanies an acid in its combinations, and gives rise to compounds altogether different from those of the acid itself; and other instances might easily be pointed out. On the whole, then, it is perhaps the most probable doctrine, that the triple prussiates are composed of bases united with super-prussiate of protoxide of iron, consisting, as it may be calculated, of three atoms of prussic acid, and one of protoxide of iron; viewed in this light, the term of *ferro-prussic acid* may still be employed, as a convenient one, to indicate that the prussic acid is accompanied by a portion of protoxide of iron, which modifies its properties, and the characters of its salts, in the same way that the appellation of siliceo-fluoric



acid denotes the fluoric acid to be accompanied by a portion of combined silex.

It remains to notice some of the more important ferro-prussiates or triple prussiates. The best known of these is the ferro-prussiate of potash, which is prepared by heating common prussian blue with dilute sulphuric acid to remove the alumina it contains, and mixing this purified compound with liquid potash, peroxide of iron is precipitated, and a yellow liquor remains, which by evaporation yields crystals of the ferro-prussiate of potash: these are purified by a second crystallization. This salt forms large crystals of a fine yellow colour, and foliated structure; it has a slightly bitter taste, is readily soluble in water, and its solution does not change vegetable colours. When the salt is strongly heated, it is decomposed, yielding complicated products, principally prussic acid, ammonia, carbonic acid, carbonic oxide, and carburetted hydrogen; charcoal, metallic iron, and potash, united with a portion of cyanogen, forming the residue. When solution of ferro-prussiate of potash is mixed with dilute mineral acids, little change happens; but on the application of heat prussic acid is evolved, and a white precipitate falls. Red oxide of mercury heated in the solution of the salt produces cyanide of mercury, peroxide of iron and potash being liberated. This salt gives precipitates with almost all the metallic oxides, which being often of deep colours are distinctive of several of the metals; these colours are stated in the following table by Thenard.

From solutions of salts of	Colour of precipitate.	From solutions of salts of	Colour of precipitate.
Iron, (protoxide,)	- White.	Platina, -	- Yellow.
(deutoxide,)	- Pale blue.	Palladium, -	- Olive.
(tritoxide,)	- Deep blue.	Silver, -	- White,
Copper, (protoxide,)	White.	changing to blue.	
(deutoxide,)	Deep brown.	Nickel, -	Apple green.



From solutions of salts of	Colour of precipitate.	From solutions of salts of	Colour of precipitate.
Cobalt, -	Grass green.	Zinc, -	} White.
Titanium, -	Reddish brown	Manganese, -	
Uranium, -	Blood red.	Antimony, -	
Gold,	} White.	Cadmium, -	
Mercury, (deutoxide,) }		Bismuth, -	
Lead, -		Cerium, -	
Tin, -			

The principal use of the ferro-prussiate of potash is as a test of the presence of iron ; it is one of great delicacy, but, as has been already remarked, in some measure uncertain, from the oxide of iron which it already contains.

The compound which is formed, when ferro-prussiate of potash is added to the solution of a per-salt of iron, is one of considerable importance, from its being the colouring matter of the beautiful pigment, Prussian Blue, and of some interest, from the difficulty of ascertaining its nature. The method of preparing this pigment has been already mentioned, (p. 657.) The alum added in the process is designed to afford alumina, which being precipitated by the potash of the triple prussiate, attracts the colouring matter, and remains combined with it, giving it more consistence, and increasing its quantity, while the colour still remains sufficiently deep.

The colouring matter formed in this process is usually regarded as a ferro-prussiate of peroxide of iron, that is, a compound of prussic acid with protoxide and peroxide of iron, in proportions which are not yet determined ; on Mr Porret's view, it is a compound of ferro-cyanic acid with peroxide of iron. Dr Thomson has found reason to doubt whether the peroxide of iron exists in it. As he remarks, when the triple prussiate of potash is added to a solution of a per-salt of iron, the precipitate which falls is of a colour much more intense than that of prussian



blue, so as to appear almost black ; hence, in the manufacture of that pigment, the protosulphate of iron is always employed, and the precipitate is only exposed in a moist state to the air, till the colour has darkened to the proper tint, and is then dried. From these facts, Dr Thomson concludes that the prussic acid and protoxide of iron are not combined with the peroxide of iron, but with the intermediate oxide, noticed by Gay-Lussac, supposed to contain an equivalent, and a third of oxygen, or to consist of 1 atom of protoxide and 2 of peroxide of iron.

The pure ferro-prussiate of peroxide of iron, obtained by adding purified ferro-prussiate of potash to a per-salt of iron, is insoluble in water, insipid and inodorous. It is not affected by dilute acids, but is decomposed by muriatic and sulphuric acids when concentrated ; the latter destroys its blue colour, and renders it white. The alkalis and alkaline earths decompose it, combining with the ferro-prussic acid, while the peroxide of iron is separated. When strongly heated it takes fire, and burns like tinder, leaving from 50 to 60 *per cent.* of oxide of iron. Heated in close vessels it yields water, prussiate of ammonia, and carbonate of ammonia, and carburet of iron and charcoal remain.

The other compounds of ferro-prussic acid are of little importance. That with barytes, used in obtaining the ferro-prussic acid uncombined with bases, is prepared by digesting prussian blue in barytic water. It forms rhomboidal crystals of a yellow colour, sparingly soluble in water. That with strontites is more soluble, but less disposed to crystallize ; that with lime, is in minute crystals of a yellowish tinge. The ferro-prussiate of deutoxide of copper is of a fine brown colour ; it was introduced as a paint by Mr Hatchett, and found superior to any brown paint in use in beauty and intensity ;



it is prepared by adding ferro-prussiate of lime to a solution of permuriate of copper in ten parts of distilled water.

SECT. II.—*Of the spontaneous decomposition of Animal Substances at low temperatures.*

THE spontaneous changes which animal matter undergoes from the reaction of its elements, are various, according to the circumstances under which it is placed.

If it be completely excluded from air and moisture, it decays with extreme slowness; indeed it may then exist for an indefinite period of time. The preservation of mummies for several thousand years depends principally on their perfect exsiccation and the exclusion of air; and the bodies of animals buried in the arid sands of Africa remain for a long period unchanged. If excluded from air, but exposed to the action of water, animal matter is converted, as has been mentioned, into Adipocire.

When atmospheric air is not entirely excluded, and when moisture with a certain degree of heat is present, the process named Putrefaction commences. The elements of the animal matter enter into new combinations, which generally pass off in the gaseous form; and an inconsiderable quantity of earthy matter remains when the process is finished. A certain temperature is necessary to this process; below  $32^{\circ}$  it appears to be arrested, as is evinced by the bodies of the mammoth and rhinoceros found in ice blocks on the northern shore of Siberia, perfectly unaltered, though they must have lain there from a time anterior to all history. The air does not seem essential to putrefactive changes by any chemical action, but a communication with the atmosphere is favourable, by allowing the elastic products to escape. The precise nature



of these combinations has not, from the offensiveness of the process, been accurately observed; and they probably vary according to the nature of the animal matter, and the circumstances under which it is decomposed. Ammonia formed by the union of the nitrogen and hydrogen of the animal matter is always disengaged in considerable quantity. Phosphuretted hydrogen appears to be produced; and to this gas, the odour, termed Putrid, is chiefly owing. Sulphuretted hydrogen occasionally forms another part of the vapours disengaged from putrefying substances, as they have often in some degree its smell, and blacken the metals,—a peculiar property of this gas. Carburetted hydrogen and carbonic acid are likewise separated. And it is probable that not only these binary combinations, but compound gases, consisting of three or more of these elements with oxygen, are formed and discharged.

Putrefaction is the great process employed by nature to restore the elements of matter to simpler forms of existence, and to prepare them again to pass through new series of combinations. Being necessarily carried on at the surface of the earth, its products are diffused through the atmosphere, dissolved by water, and absorbed by the soil: they furnish the principal nutritious matter for the support of vegetables, and are thus again adapted to the nourishment of animals.



the combination has not been the object of the present paper, but it is observed, and they propose, according to the nature of the animal matter, and the circumstances under which it is decomposed, to search for the nature of the nitrogen and hydrogen of the animal matter is always changed in composition. I have observed hydrogen appears to be absent; and to this fact the above remark I think may be applied. I have observed hydrogen occasionally forms another part of the various changed from pure hydrogen, and they have been in some degree of the same, and I think the result is a mixture of the gas, I observed hydrogen and carbonic acid are the same separated. And it is probable that not only these binary combinations, but compound gases consisting of three or more of the elements with oxygen, are liquid and dissolved.

Respiration is the great process employed by nature to remove the elements of matter to a higher form of existence, and to prepare them again to pass through new cycles of combination. Being necessarily carried up to the surface of the earth, its products are dissolved through the atmosphere, absorbed by water, and absorbed by the soil; they furnish the principal nutritious matter for the support of vegetables, and are thus again adapted to the support of animals.



## APPENDIX.

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### BROME.

IT has been already stated, (vol. i. p. 716.) that a new substance, which appears, as far as has been yet determined, to be of a simple nature, has lately been discovered by M. Balard of Montpellier, to which the name of BROME has been given. It exists in sea-water, and in some marine plants. When obtained in a pure state, its properties and chemical agencies are very similar to those of Chlorine and Iodine ; it appears to form an acid with oxygen, and one more powerful with hydrogen ; and the salts of the latter acid are conceived not to exist in the dry state, but, like the muriates and hydriodates, to become compounds of the metallic bases with the element brome. The name which was first applied to this substance was that of *muride*, but it has since been changed to Brome, an appellation derived from the Greek word *βρωμος*, (graveolentia,) denoting its strong disagreeable odour. The original memoir of M. Balard was published in the *Annales de Chimie* for August 1826. An abstract of it will be found in the Quarterly Journal of Science, vol. 22.

To obtain brome, two methods have been employed. On adding solution of chlorine to the *bittern* of sea-water, or to the washings of the ashes of sea-weed, a yellow saline liquor, having a peculiar odour, is produced : this is distilled, and the product, which has a stronger odour, is heated : the red vapours that arise are passed over chloride of calcium, and condensed in a small receiver. By this method very little is procured, a single drop being considered a successful result. A better process is to pass chlorine gas through



bittern, then to agitate the liquor with ether, which dissolves all the brome, and rises to the surface of a rich hyacinth colour. This ethereal solution is to be poured off and mixed with caustic potash, which forms immediately hydro-bromate of potash; and by employing the ether repeatedly in this manner, to abstract the brome and convey it to the potash, a neutral solution of the hydro-bromate of potash is obtained, which, by evaporation, yields the salt in cubic crystals. These are to be mixed with peroxide of manganese and sulphuric acid, diluted with half its weight of water, and distilled in a small apparatus; the red vapours of brome are condensed in a receiver full of cold water, and by distillation over chloride of calcium the brome is obtained dry and pure.

Brome presents the peculiarity of existing in the liquid form, being, except mercury, the only simple fluid with which we are acquainted. It appears dark red by reflected light, hyacinth red by transmitted light; its odour is disagreeable, somewhat resembling that of euchlorine; its taste is strongly sapid. It acts rapidly on animal matter; dropt on the skin it renders it yellow, and corrodes it; if applied to the skin for a short time only, the stain is not permanent. It destroys animal life; even a single drop of it placed on the beak of a bird was found sufficient to kill it. Brome remains fluid when cooled to zero; its specific gravity is 2.965. It is highly volatile, emitting at common temperatures copious red fumes like those of nitrous acid; it boils at  $116.6^{\circ}$ ; the vapour does not sustain the combustion of a taper; several of the metals, however, burn in it. Brome is not affected by light or heat; it may be passed through red hot glass tubes without change, nor does it appear that galvanism produces any indication of decomposition. It is soluble in water, in alcohol, and still more so in ether. It does not redden litmus, but, like chlorine, bleaches it; it destroys even more permanent colours, as that of indigo. It combines with hydrogen, as will be mentioned, forming Hydro-bromic acid; this combination is not, however, affected, like that of chlorine and hydrogen, by the agency of light, but requires the application of heat. It unites with metals, forming bromides, which, when dissolved in water, becomes hydro-bromates of oxides; passed in vapour over potash, soda, barytes, and lime, at a red heat, it ex-



pels their oxygen with vivid incandescence, and takes its place. When dissolved in solutions of these bases, its odour and colour disappeared; the compounds still, however, retained the bleaching power, and the addition of an acid evolved brome; they were, therefore, bromides of these oxides, similar to the chlorides of lime, potash, &c. Brome also unites with chlorine, iodine, sulphur, and phosphorus. Its equivalent seems to be about 75 or 76, to hydrogen as 1.

**HYDROBROMIC ACID.**—This acid gas, analogous to the muriatic and hydriodic, may be obtained by decomposing the hydrobromate of potash by sulphuric acid; but, as thus procured, it is mixed with muriatic and sulphurous acids. Or it may be formed by mixing hydrogen with the vapours of brome, and introducing a red hot iron; even in this way the combination is, however, imperfect. A third method is to mix the vapour of brome with sulphuretted or phosphuretted hydrogen gas, or with hydriodic acid gas; these gases will be decomposed, their other elements separated, and hydrobromic acid gas produced. But the method which is found to succeed best, is similar to that for preparing hydriodic acid, mixing brome with phosphorus, and moistening the mixture; the gaseous acid is abundantly produced, and may be collected over mercury.

Hydrobromic acid gas is colourless; it has a pungent odour and an acid taste; when it escapes into the air it produces very dense white vapours, which excite coughing when inspired. It suffers no change when passed with oxygen gas through a red hot tube; at the same time no change happens when water and brome are, in like manner, transmitted through a heated tube. Chlorine, however, decomposes it, producing muriatic acid gas and vapours of brome, which are absorbed by the mercury: iodine does not produce any decomposition of this kind. The acid is not affected by mercury, but potassium and tin, when heated, combine with the brome and evolve the hydrogen gas, the volume of which is equal to half of the original bulk: hydrobromic acid thus consists of equal volumes of hydrogen and vapours of brome, united without condensation, resembling in composition the muriatic and hydriodic acids; this is shown also in the decomposition of hydriodic acid



gas by brome, the hydrobromic acid occupying the same volume as the gas which is decomposed. The equivalent of hydrobromic acid will thus be 76 or 77, according to that of brome; the density of the acid gas may hence be calculated to be about 2.6, and that of the vapour of brome is supposed to be 5.135. In these characters brome appears to be intermediate between chlorine and iodine, having an affinity to hydrogen weaker than that of the former, but stronger than that of the latter; its equivalent is also nearly the mean between 36, that of chlorine, and 124, that of iodine.

Hydrobromic acid gas is rapidly absorbed by water; from the condensation much heat is evolved, and when the solution is saturated it forms a dense fuming liquid: this fluid acid dissolves brome, becoming of a red colour; when heat is applied, the brome is driven off in vapour with a portion of the acid. Chlorine decomposes the liquid acid evolving brome; nitric acid forms with it a compound acid, resembling nitromuriatic acid in the power of dissolving gold and platina. Liquid hydrobromic acid is partially decomposed by sulphuric acid, producing brome and sulphurous acid; in this circumstance it resembles hydriodic acid. Iron, zinc and tin are dissolved by hydrobromic acid, with an evolution of hydrogen. The acid acts on oxidated bases in exactly the same manner as muriatic and hydriodic acids with the alkalis and earths; with the oxides of iron, and the peroxides of copper and mercury, it forms soluble salts; with oxides of lead and silver, and protoxide of mercury, and several others, insoluble compounds are produced, which are hence regarded as metallic bromides; these compounds are readily distinguished by becoming yellow when heated with chlorine, nitric acid, or chloric acid, from the abstraction of hydrogen and the liberation of brome. Peroxide of manganese evolves brome from hydrobromic acid.

BROMIDE OF POTASSIUM may be formed by direct combination; by introducing potassium into the vapour of brome, a vivid combustion and even detonation happens, and a white compound is produced. Or it may be procured by saturating hydrobromic acid with potash and evaporating the solution; the hydrogen of the



acid and oxygen of the potash unite to form water, and the bromide of potassium crystallizes in cubes. It has a sharp taste, decrepitate when heated, and fuses unchanged. Chlorine, aided by heat, displaces the brome; iodine is unable to produce this effect; on the contrary, brome displaces iodine from the iodide of potassium.

HYDROBROMATE OF AMMONIA is formed by mingling equal volumes of the two gases; it crystallizes in long white prisms, is volatile, and when exposed to moist air becomes yellow and acid. HYDROBROMATE OF MAGNESIA is uncrystallizable, deliquescent, and, like the muriate, easily decomposed by heat. HYDROBROMATE OF BARYTES is very soluble in water, and is also dissolved by alcohol; it forms opaque mamillary masses, unlike the crystallized muriate of the base.

BROMIDE OF LEAD is a yellow insoluble powder, fusible by heat. BROMIDE OF TIN is obtained by evaporating the solution of hydrobromate of tin. Tin burns when in contact with brome, and a solid white crystalline Bi-bromide of tin is formed. Nitric acid evolves brome. BROMIDE OF MERCURY is produced by adding an alkaline hydrobromate to protonitrate of mercury; it falls in the state of a white precipitate, resembling calomel. The direct action of brome on mercury produces a Bi-bromide very similar to corrosive sublimate; it may be sublimed by heat, is soluble in water, alcohol and ether, and affords peroxide of mercury when decomposed by alkalis; it is distinguished by yielding, like other bromides, red vapours of brome when acted on by nitric acid. BROMIDE OF SILVER, obtained by precipitation from the nitrate, is yellowish white when thrown down, but becomes black from the agency of light; it is soluble in ammonia, but not in nitric acid; it is decomposed by nascent hydrogen; when fused by heat it forms a reddish horn-like substance. BROMIDES OF GOLD AND PLATINA, obtained by digesting the metals in bromo-nitric acid, are yellow compounds, which are decomposed by heat; the latter gives yellow precipitates with potash and ammonia.

BROMIC ACID. When brome is dissolved in a concentrated so-



lution of potash, or when solid potash is mixed with the ethereal solution of brome, a reaction happens, similar to that which occurs when chlorine is passed through a strong alkaline solution; one portion of the brome combines with the hydrogen of a part of the water, forming hydrobromic acid, and the rest of the brome, uniting with the liberated oxygen, becomes bromic acid; two salts are thus formed, hydrobromate and bromate of potash; the latter being sparingly soluble, is deposited in crystalline scales. Bromate of potash, when heated, gives out pure oxygen gas, becoming a bromide of potassium; it deflagrates on burning fuel; mixed with sulphur it detonates on being struck with a hammer. This salt throws down a white precipitate from solution of nitrate of silver, and a yellowish white from protonitrate of mercury. Bromates of the other alkalis and earths, except magnesia, may be procured by the same process; they are decomposed by hydrobromic and muriatic acids; sulphuretted hydrogen and sulphurous acid decompose them in the same manner as they do the iodates.

Bromic acid may be obtained uncombined by adding sulphuric acid to a dilute solution of bromate of barytes. It has a very sour taste, reddens and then destroys the colour of litmus; it is decomposed by deoxidizing agents, as sulphurous acid. It appears to consist of one atom of brome and five of oxygen, coinciding in this respect exactly with the chloric and iodic acids; its equivalent is 115 or 116.

Brome condenses olefiant gas, forming an oily fluid like that produced by chlorine. Brome forms with sulphur a reddish fetid liquid like the chloride, and with phosphorus it produces two yellow compounds, a bromide and bi-bromide of phosphorus. When chlorine gas is passed through brome, there results a chloride of brome, which condenses into a reddish yellow fluid, having a penetrating odour, and a disagreeable taste; it was very volatile, emitting yellow vapours; metals burn in it; it is soluble in water, and retains a bleaching power. With iodine brome forms a reddish brown solid, and a dark-red liquid compound.

As to the sources of brome, it appears to exist in sea-water in the state of hydrobromate of magnesia; it may be detected also in the ashes of sea-weed, by the yellow tint which their lixivium yield



when heated with chlorine ; likewise in the ashes of the *Ianthina violacea* ; and it has been suspected to be present in a mineral spring near the Pyrenees.

The similitude of the properties of brome, to those of chlorine and iodine, is certainly very striking, and might lead us to suppose that it is a compound of one or other of these bodies, or, as M. Balard at first suspected, that it is an unknown combination of these two elements with each other. He has stated, however, in the able memoir which contains all that is as yet known of this substance, that by no method could he detect either chlorine or iodine in it ; nor did he, in any of its chemical agencies, discover any indication of its being decomposed. It is hence regarded as a simple substance, intermediate in its properties between chlorine and iodine ; and Vauquelin, Gay-Lussac and Thenard, in their report to the French Institute respecting M. Balard's researches, consider this opinion to be one highly probable, though it can be fully established only by more minute investigation.

*Old and New Theories as to the nature of Muriatic Acid, and Oxymuriatic Acid or Chlorine.*

In the first volume, it was mentioned, (p. 669, and Preface, p. viii.) that the new doctrine of the nature of muriatic acid would, from its being so generally adopted, be exclusively followed in the text of this edition, though the evidence, both from general reasoning and experimental results, especially those brought forward by my Father, appears to me to be decisive in favour of the older theory. An abstract, it was mentioned, of the reasoning, and an account of the experimental researches of my Father, would be given in the Appendix, and a few remarks would be added as to the present state of the question. The comparative view of the arguments in favour of each doctrine may first be given, as it was stated by Dr Murray in the former editions of this work, and in his *System of Chemistry*, (vol. ii. p. 421.)

Muriatic acid gas, it has been stated, is procured by mixing muriate of soda, or, as it is called on the new theory, chloride of so-



consequence of the decomposition of the acid and of the bases, the hydrogen of the former uniting with the oxygen of the latter, while the chlorine combines with the reduced metals. The evolution of hydrogen which attends the action of muriatic acid gas on metals, may, in like manner, be owing to its decomposition, the chlorine combining with the metal, and the hydrogen being disengaged. The reason why muriatic acid cannot be expelled from dry salts may be, that it does not exist in them, that they are compounds of chlorine and metallic radicals, and the presence of water is therefore necessary to afford oxygen for the base, and hydrogen for the production of the acid. The formation of muriatic acid gas, when chlorine and hydrogen are exposed to the light mingled together, may be, not a production of muriatic acid and its combined water, but a simple union of the two gases to form the acid gas. Thus, all these facts may be explained on the later view of the constitution of muriatic and oxymuriatic acids; and no oxygen being capable of being abstracted from oxymuriatic acid, unless water be present which may afford it, there is no evidence, it is contended, that oxymuriatic gas is a compound, but, on the contrary, the most strict inference is, that it is a simple body.

It is not easy to give a distinct and condensed view of a subject so complicated, but I shall endeavour to state the question in the simplest form.

The leading fact is, that when oxymuriatic gas and hydrogen gas are submitted to mutual action, muriatic acid gas is the only sensible product. Did we know nothing of the constitution of muriatic acid gas, the most direct conclusion from this experiment would be, that it is a case of simple combination, and that, therefore, muriatic acid is a compound of these two gases. But before drawing such a conclusion, it is necessary to inquire whether muriatic acid gas is real muriatic acid or not; and if there are grounds for drawing any inference with regard to its composition, this must be kept in view in the conclusion to be drawn with regard to this leading experiment, and all the weight that is due to them must be allowed.

When we submit muriatic acid gas to the action of substances with which acids in general combine, and by which they are neu-



tralized, (alkalis for example, earths or metallic oxides,) there is this apparent neutralization, and at the same time a quantity of water is obtained. What is the conclusion to be drawn from this? The most simple and direct one is, that the acid and the base have combined together, and that the water obtained has been derived from the muriatic acid gas,—that muriatic acid gas, therefore, is not the real acid, but contains a portion of combined water.

Is this evidence of the existence of water in muriatic acid gas conclusive? All that can be said in reply to this is, that it is the same as that by which its existence in other acids is proved: the phenomena in both cases are precisely alike,—the apparent neutralization of the acid and of the base, the formation of a product having saline properties, and the production of a quantity of water. If we add sulphuric acid to oxide of lead, there will be the neutralization of the acid, the formation of a compound of sparing solubility, and a portion of water will be obtained. If nitric acid vapour be transmitted over potash, there will be the mutual neutralization of the acid and alkali, and the production of a saline compound from which water can be expelled by heat, exceeding in quantity the water which the potash contained. We admit the proof from these facts as conclusive, that combined water has existed in sulphuric and nitric acids. But the phenomena from the action of muriatic acid gas on oxide of lead, or on potash, are exactly the same, and might be justly stated in the very same terms. The induction equally follows, therefore, that it contains water, and rests on evidence the same as that which is received as conclusive with regard to others.

The only peculiarity with regard to muriatic acid is one of little importance,—that of its existence in combination with water, in the gaseous form, at natural temperatures. It is obvious that this makes no essential distinction. Temperature is merely relative, and *a priori* it is just as probable that a compound of an acid with water should be gaseous as that it should be liquid or solid. Yet it is probable, that the not attending to this obvious conclusion has been the cause of any difficulty being supposed to be attached to the admission, that muriatic acid contains combined water, and that had this acid, like the sulphuric or nitric, been liquid at na-



consequence of the decomposition of the acid and of the bases, the hydrogen of the former uniting with the oxygen of the latter, while the chlorine combines with the reduced metals. The evolution of hydrogen which attends the action of muriatic acid gas on metals, may, in like manner, be owing to its decomposition, the chlorine combining with the metal, and the hydrogen being disengaged. The reason why muriatic acid cannot be expelled from dry salts may be, that it does not exist in them, that they are compounds of chlorine and metallic radicals, and the presence of water is therefore necessary to afford oxygen for the base, and hydrogen for the production of the acid. The formation of muriatic acid gas, when chlorine and hydrogen are exposed to the light mingled together, may be, not a production of muriatic acid and its combined water, but a simple union of the two gases to form the acid gas. Thus, all these facts may be explained on the later view of the constitution of muriatic and oxymuriatic acids; and no oxygen being capable of being abstracted from oxymuriatic acid, unless water be present which may afford it, there is no evidence, it is contended, that oxymuriatic gas is a compound, but, on the contrary, the most strict inference is, that it is a simple body.

It is not easy to give a distinct and condensed view of a subject so complicated, but I shall endeavour to state the question in the simplest form.

The leading fact is, that when oxymuriatic gas and hydrogen gas are submitted to mutual action, muriatic acid gas is the only sensible product. Did we know nothing of the constitution of muriatic acid gas, the most direct conclusion from this experiment would be, that it is a case of simple combination, and that, therefore, muriatic acid is a compound of these two gases. But before drawing such a conclusion, it is necessary to inquire whether muriatic acid gas is real muriatic acid or not; and if there are grounds for drawing any inference with regard to its composition, this must be kept in view in the conclusion to be drawn with regard to this leading experiment, and all the weight that is due to them must be allowed.

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tural temperatures, the inference would have been admitted with regard to it, with as much facility as a similar inference with regard to these acids.

The nature of muriatic acid gas being thus inferred, and the existence of combined water in it being established, we are enabled to draw the just conclusion with regard to the mutual action of oxymuriatic and hydrogen gases. Since it is the entire product of their action, no other conclusion can be drawn, than that the oxymuriatic gas is a compound of real muriatic acid and oxygen, and that its oxygen enters into union with the hydrogen, forming the water which the acid holds combined with the muriatic acid in the gaseous form.

The production of water from muriatic acid gas may no doubt also be explained, however, in a different manner. Assuming that oxymuriatic gas or chlorine is an undecomposed substance which with hydrogen forms muriatic acid gas, then, when this gas is submitted to the action of metallic oxides, and water is produced, it may be held that the water is formed by the oxygen of the oxide combining with the hydrogen of the acid, while the chlorine unites with the metal. This is accordingly the explanation of the new doctrine. But is there any conclusive proof of it? There is none. It is either mere assumption, or else reasoning in a circle by a previous assumption of what is to be proved, and does not even, like the opposite explanation, derive any support from analogy.

When muriatic acid gas is submitted to the action of substances which impart oxygen easily, to black oxide of manganese for example, oxymuriatic gas is formed and water is deposited. According to the old doctrine, the muriatic acid deposits its combined water, and unites with the oxygen. According to the new, the muriatic acid is decomposed, its hydrogen combines with the oxygen and forms water, while its other element, the chlorine, is liberated. Is there any absolute proof of the one of these conclusions more than of the other? There is not. Both are possible explanations of the phenomena. And the explanation, according to the old doctrine, is more simple and more conformable to analogy than the other.



When a solution of oxymuriatic gas in water is exposed to the rays of the sun, oxygen gas is collected, and muriatic acid remains combined with the water. The obvious explanation here is, that by the agency of light, the oxymuriatic acid is resolved into muriatic acid and oxygen. The results may no doubt, however, be explained in another mode, that the water is decomposed, its oxygen liberated, and its hydrogen combined with the chlorine to form muriatic acid. But is there any proof of this? There is none. The presence of the water, it is said, is necessary to the result. If it is not present, no oxygen is evolved, and the oxymuriatic acid remains unchanged. Therefore the water must be decomposed. No such conclusion, however, follows. Could the agency of the water be explained in no other mode, it would at least be a presumption of it. But it is at once accounted for by the necessity of water to the existence of muriatic acid, in common with other powerful acids, in an insulated form; and this explanation has all the support which this striking analogy affords. The other is both complicated, and altogether gratuitous.

Oxygen, it is said, is not abstracted in other cases in which it ought to be if it existed in oxymuriatic gas. Charcoal, for example, heated to the utmost intensity in the gas, produces no change, yet charcoal at a high temperature has a very powerful attraction to oxygen, and if oxymuriatic acid is decomposed with so much facility by solar light, it might with equal facility yield its oxygen to charcoal. Much stress was laid on this fact by Sir H. Davy: it first led him indeed, he affirmed, to doubt of the existence of oxygen in oxymuriatic gas. Could no cause be assigned for it, it would no doubt be of considerable weight. But nothing is more easy than to assign a sufficient cause. To admit of the transition of oxymuriatic acid to the state of muriatic acid, a portion of water, essential to the existence of the latter in an insulated state, must be supplied: this the charcoal cannot yield. Whatever therefore may be the strength of attraction which it exerts to oxygen, muriatic acid gas cannot be formed; and as the product of the oxygenation of charcoal is not a substance exerting affinities to acids, the muriatic acid cannot in this, as in the case of the action of metals on oxymuriatic gas, pass into a state of new combination. The actual



result is therefore conformable to what is to be looked for,—the oxymuriatic gas suffers no change. It presents, therefore, no difficulty in the old doctrine; nay, it becomes a powerful argument in its support, and not less adverse to the new; for, if chlorine be an element like oxygen, exerting affinities to inflammable bodies, and combining with them, why does it not combine directly with charcoal? This is an *instantia crucis*. It is precisely what we should expect in conformity to the one, and the reverse of what would be looked for according to the other.

Some have affected to consider the one doctrine as a theory, the other as an hypothesis. There is no proof, they say, of the existence of oxygen in oxymuriatic acid gas, or of the existence of water in muriatic acid gas. The one therefore must be regarded as a simple substance, and the other as real muriatic acid. They forget that this is taking for granted the points in dispute. There are facts whence the existence of oxygen in oxymuriatic gas and of water in muriatic acid gas are inferred. The same facts may no doubt be explained by other conclusions. But these are not more certain, and the system involved in them is in many of its parts as defective in strict evidence, and as hypothetical as the other. The whole, in fact, forms two systems, embracing an extensive series of phenomena, neither of them demonstrated, and the superior probability of which must be determined from their application in all their extent.

Under this point of view, no conclusive evidence, I have endeavoured to shew, has been brought forward in support of the new hypothesis, and its explanations are more complicated, and more at variance with analogy, than those of the opposite opinion.

What inference can be more probable *a priori* than that muriatic acid should contain combined water? All the other powerful acids do so, and its affinity to water does not seem to be less strong than theirs. Or what conclusion can be less conformable to analogy, than that it alone of all the powerful acids should exist altogether free from water in an insulated state? If these other acids did not contain combined water, the inference that muriatic acid gas did so might be regarded as improbable, and as an adaptation to an hypothesis. But when they do contain combined water, the



inference is not only confirmed by all the probability it derives from this strict analogy, but the opposite conclusion, that it does not contain combined water, becomes as highly improbable, and as obviously an adaptation to hypothesis in violation of analogy.

A few analogies support the hypothesis of chlorine. Sulphur, for instance, forms an acid by combining with hydrogen. Chlorine, therefore, considering it as a simple substance, may also be supposed to form an acid in combining with the same element. But there is no analogy whatever between muriatic acid and sulphuretted hydrogen, while there is the closest analogy between it and the acids which contain oxygen with combined water.

The discovery of a new substance, Iodine, which has relations in several respects analogous to chlorine, gave considerable support to the new system, and chiefly contributed, as Gay-Lussac has remarked, to fix the opinion of the greater number of chemists in its favour. Yet iodine has little analogy in properties to chlorine; and were the analogy more strict than it is, it would only serve to render more probable the conclusion which some considerations suggest, that iodine is a compound, and an oxidated body.

The substances which muriatic acid forms when it acts on the alkalis, earths, and metallic oxides, have all the properties of neutral salts. Many of them have the saline taste, are abundantly soluble in water, crystallizable, some are deliquescent, others efflorescent, and in no respect do they differ in general properties from other saline compounds. Yet we are to believe, on the new hypothesis, that they are not salts, but consisting of chlorine and metals, are rather similar to metallic oxides. No conclusion can appear more improbable, and none more strictly conformable to analogy than the other.

So far the one doctrine is superior to the other. The latter, however, is still to be regarded as a possible hypothesis which may be maintained. It were desirable, therefore, to obtain evidence of such a nature as to establish the one to the exclusion of the other. With this view, I have made a number of experiments, (communicated in Nicholson's Journal, vol. xxviii. &c.) of which, however, I can give only the most general notice.

The question may be decided, either by proving the existence of



oxygen in oxymuriatic gas, or the existence of water in muriatic acid gas. In one series of experiments directed to the former of these objects, carbonic oxide was submitted to the action of oxymuriatic acid gas with a portion of hydrogen gas, the latter being added with the view, that by forming a certain portion of water with the oxygen of the oxymuriatic acid, it might favour so far the transition to the state of muriatic acid, and favour therefore the farther communication of oxygen to the carbonic oxide, so as to convert it into carbonic acid. The result was the production of a portion of carbonic acid,—a result inconsistent with the new hypothesis, since according to it there is no source whence oxygen could be communicated. In another series of experiments, the object was to gain proof of the existence of water in muriatic acid gas, from results which could not be otherwise explained. The production of water, when the acid is combined with any oxidated base, as the fixed alkalis, the earths, or the metallic oxides, is so far liable to ambiguity, that it can be accounted for on the new doctrine, by supposing the water to be formed by the oxygen of the base combining with the hydrogen assumed to exist in the acid. But there is one substance which may be employed free from this ambiguity,—ammonia; it contains no oxygen, and if water be obtained when muriatic acid gas is combined with it, there is no mode of accounting for it, but by the conclusion that it is derived from the muriatic acid gas. On making the experiment, with the necessary precautions to exclude extraneous moisture, water was obtained. The quantity was, indeed, inferior to that which may be obtained from combinations of the acid in which the product is insoluble and fixed; for the volatility of the ammoniacal salt, and the attractive force with which water is retained in it, counteract the separation, while in compounds having no apparent attraction to water, and to which from their fixity a high degree of heat can be applied, the separation can be rendered much more complete. But still the obtaining any water is a conclusive result, since, according to the new hypothesis, none whatever ought to be obtained.

The results in both these series of experiments were at first denied. It was affirmed, that the carbonic oxide remains unchanged, and that no carbonic acid is obtained; but the reverse of this was



afterwards admitted, and attempted to be accounted for, by the supposed operation of a new gas, a compound of oxymuriatic gas and carbonic oxide, called the chloro-carbonous acid, which, decomposing water, forms muriatic and carbonic acids.

With regard to the experiment with the muriate of ammonia, it was at first asserted, that it does not yield the most minute trace of water, unless it has been previously exposed to the atmosphere, from which it was supposed to attract moisture. I showed, by diversified experiments, that the salt absorbs no moisture from the air in the common state of dryness and temperature in which the experiment was performed. A portion of the salt, formed by the union of the two gases, was exposed to the air in the scale of a balance; at the end of fifteen minutes it had not increased in weight by the smallest quantity, though exposed in a thin layer to the air; and at the end of an hour, it had only gained an increase of a quarter of a grain, not equal to one-fourth of the water which it yields by heat. At the end of two hours, its increase of weight was altogether only half a grain; and in the course of two days, it did not appear to grow any heavier; and in another experiment, the salt gained no increase of weight whatever. I also showed, that it did not afford water in larger quantity when it had been exposed to the air in the freest manner, than when it had been excluded from the air. Likewise, that when, by the application of heat, a portion of water was driven off from it, and condensed in globules in the neck of the retort, this water was not re-absorbed by the salt inclosed with it, though the retort was allowed to stand for twenty-four hours. Lastly, it was shewn, that when the salt was heated without the air being admitted at all, water is obtained from it, though, from the circumstances attending this mode of conducting the experiment being unfavourable to the expulsion of the water, the quantity is rather less than what is procured in the other mode, (Nicholson's Journal, vol. xxxii. p. 185, xxxiv. p. 264.) It was at length admitted, that water is produced in small quantity, even when the air has been excluded; but it was then supposed, that this must have existed in the state of hygrometric vapour in the gases, however carefully they were dried, the ammonia, by exposure to the action of potash, and the muriatic acid by being confined with mu-



riate of lime. For such an assumption there is not the slightest foundation. Dr Henry had shewn, that ammonia, after exposure to potash, retains no trace of aqueous vapour, that it may be cooled to zero without any indication of moisture, and that electricity resolves it into hydrogen and nitrogen, without any appearance of moisture or oxygen. Dr Henry obtained the same results with muriatic acid when dried by muriate of lime ; and Gay-Lussac and Thenard farther found, that the fluoboric acid gas, the most delicate test of the presence of moisture, did not in the slightest degree affect the transparency of muriatic acid gas ; and conversely, that when the acid gas had been carefully dried, a drop of water introduced into it, instead of diminishing by evaporation, increased in bulk. It is thus altogether impossible that such a quantity of hygrometric vapour could exist in the gases as would account for the copious dew obtained by heating muriate of ammonia.

The only circumstance rendering the result less decisive than it otherwise would be, is that the quantity of water is not considerable, and is less than what is obtained by means of other combinations, into which muriatic acid enters with salifiable bases. But this is to be expected from the volatility of the ammoniacal salt, in consequence of which, the same degree of heat cannot be applied to overcome the attraction by which the water is retained. If the other muriates yield the greater part of their water only when raised nearly to a red heat, (which is the case,) it is not to be supposed that muriate of ammonia shall do so at a temperature so much lower as that which it can sustain without volatilization. What is to be expected is a certain portion of water, greater as the arrangements are better adapted to obviate the peculiar difficulty attending the experiment. There is a production of ammonia in every form of it ; and there exists no just argument whence it can be inferred that the quantity is less than what ought to be obtained. On the opposite doctrine none whatever should appear.

To effect as much as possible the separation of the water from the muriate of ammonia, I added the experiment of subliming it through an ignited tube, either alone, or containing charcoal which had been previously thoroughly calcined. A larger quantity of wa-



ter was procured by the effect of the higher temperature thus favourably applied.

Dr Ure afterwards performed the experiment by subliming sal-ammoniac over ignited metals in a tube, and with the same result of a production of water. The only objection that could be made to this experiment was, that the common sal-ammoniac was employed, and not that formed by the combination of the dried gases. I repeated it with the salt thus prepared from the union of the two gases previously carefully dried, and with a similar result.

I afterwards repeated the original experiment, that of obtaining water from the salt by heat alone, with the variation of conducting it in an apparatus on the principle of the Cryophorus of Dr Wollaston. A retort in which the dry gases were combined was connected with a similar retort, the joining being secured by cement; the former retort, containing the salt, was heated in oil to  $420^{\circ}$ , and the other surrounded with a freezing mixture; the latter, at the end of the experiment was found incrustated with a film of ice.

In these experiments a considerable portion of water was thus obtained. It occurred to me that muriatic acid, in its gaseous form, might be employed in a similar manner. I accordingly found, in a series of experiments, executed in various modes, that when muriatic acid gas, previously thoroughly dried by exposure to muriate of lime, is transmitted over ignited iron-filings, or is heated in a retort, from which the air is excluded, with iron or zinc, a portion of water is obtained. The quantity of this water was estimated to amount to about the fifth of the whole quantity of combined water which muriatic acid is calculated to contain, (*Transactions of the Royal Society of Edinburgh*, vol. viii. p. 287.) All the circumstances of these experiments tended to preclude any of the suppositions of the presence of hygrometric vapour, or other external sources from which the water, procured in former experiments, was imagined to proceed. No arrangement could be supposed better adapted to prove, that any deposition of water must be by separation from its existence in the gas in a combined state.

But while these results are subversive of the new doctrine, they seem to present a difficulty not easily explained even by the old theory. The combined water of the muriatic acid gas must, of



course, be liberated when the acid enters into combination ; but the acid cannot unite with metals unless they are previously oxidated, and this oxidation must be performed at the expense of the water liberated ; a dry muriate and hydrogen must therefore be produced, and from the doctrine of equivalent combining quantities no water ought to appear. The most probable explanation of the result seems to be, that a super-muriate of the oxide of the metal is formed, and that it is only the water of this excess of acid fixed in the compound which is evolved. Accordingly, the portion of water procured was rather less than a grain, from 43 cubic inches or 16.8 grains of muriatic acid gas, or about a fifth of the water existing in the whole of the acid gas, a quantity much larger than what can be attributed to any external source, yet easily accounted for on the supposition of a super-muriate being produced. I ascertained, what confirms this opinion, that the muriates formed, when dissolved in a small portion of water, were always strongly acid, and that, moreover, the quantity of hydrogen evolved was always less than half the volume of the muriatic acid gas employed.

Sir H. Davy has asserted, with regard to these last experiments, that the water is produced, either from the combination of hydrogen disengaged from the muriatic acid by the metal with the oxygen of the air in the tube, or by the action of the acid on the oxide of lead and the alkali in the glass. These causes, I believe, have little or no influence on the result. The water does not appear until after the air in the tube has been entirely expelled by the muriatic acid gas. And were it even granted, that at a red heat the glass is liable to be acted on by the acid, in the greater number of the experiments I performed, the heat applied was much lower, and the glass did not exhibit the slightest appearance of being acted on. The objection is not better founded than the one formerly maintained, that the water is derived from absorption from the atmosphere.

Such are the clear and forcible arguments and statements of experimental results given by my Father. In the few additional remarks which I shall make, I shall consider, first, the general reason-



ing on the subject, and afterwards the experiments performed by Dr Murray.

The principal argument which has been on all occasions brought forward in support of the new doctrine, is the assertion already noticed, (p. 692,) that it is not an hypothesis, but a simple expression of facts ; and it is partly, perhaps, from the confidence with which this has been affirmed, that the general adoption of that doctrine has arisen. Yet nothing is clearer, when the assertion is examined, than that the new opinion is merely an inference from facts, and one entirely hypothetical. To take, for instance, the experiment, which is in some measure the basis of the doctrine : When oxymuriatic acid and hydrogen gases are mingled together and exposed to light, the whole mixture is converted into muriatic acid gas without any other apparent product. Muriatic acid, therefore, says Sir H. Davy, is a compound of oxymuriatic acid and hydrogen ; and this, he adds, is a simple expression of a fact. But this is a mistake. It is a simple expression of a fact, that from the mutual action of oxymuriatic acid gas and hydrogen gas, muriatic acid is obtained : this proposition will for ever remain true, and cannot be contradicted. But that muriatic acid gas is a compound of oxymuriatic acid and hydrogen, is an inference from the fact ; and it is not the only inference which may be drawn from it. There is another, which, when the subject is considered in all its bearings, is equally, perhaps more probable ; and as long as another view can be given of the phenomena, the new doctrine can never be called merely the expression of a fact. Even if no other explanation could be given in the present state of our knowledge, it would still remain an inference not necessarily just, and which by the progress of science might be subverted ; it would remain possible, that either oxymuriatic acid or hydrogen gas, or both, might be discovered to be compounds, and that the result of their mutual action in the production of muriatic acid is much more complicated than simple combination. But since another opinion as to the changes that happen actually can be maintained, namely, that the elements are arranged not as oxymuriatic acid and hydrogen, but as muriatic acid and combined water, this is a sufficient proof that neither of the views can be called a statement of facts, but that both are hypotheses.



It is no doubt the most direct conclusion from this experiment, that the two gases have simply combined; but the most direct and obvious conclusion from an experiment may not always be the just one. The shortest way of proving this, says Dr Murray, is to state, in the very same form of expression, propositions which the advocates of the new doctrine will not admit. I combine, I may say, protoxide of mercury and muriatic acid, and form calomel; I conclude, therefore, that calomel is a compound of muriatic acid and oxide of mercury. I combine muriatic acid and potash, and, by dissipation of the water, I obtain a solid product, which I consider as a compound of the muriatic acid and potash; and I perceive in these conclusions no supposition, but a simple expression of facts. I pass nitric acid vapour over potash, and obtain nitrate of potash; in like manner I pass muriatic acid gas over potash, and the compound which is formed I hold to be muriate of potash. I heat muriatic acid with peroxide of manganese, and find oxygen and muriatic acid to disappear, and oxymuriatic acid to appear; and conversely, I expose a solution of this product to solar light, and recover oxygen and muriatic acid. These and other similar instances I regard as simple statements of facts, unmixed with any hypothesis. Such are the propositions which, on the old theory, may be laid down, because they are the most obvious conclusions from the phenomena; yet every one of them will be contradicted by the supporters of the new doctrine,—a clear proof, that the most direct inference from a fact is not to be always admitted as necessarily the just one.

The cause of errors such as this is, and which has long been recognised as the fertile source of false speculations in physics, is the taking into view only part of the facts which belong to the subject—those which appear most favourable to our induction, instead of taking the whole into consideration, and from this general view forming the most probable conclusion. The two views of the nature of muriatic and oxymuriatic acid will each of them appear a legitimate induction from facts, according to the light in which it is viewed, and the phenomena to which it is applied, while each will require the aid of hypothetical assumption, when extended to all the phenomena. If we look only to the experiment in which oxy-



muriatic acid is obtained from black oxide of manganese and muriatic acid, or to that in which oxygen gas is obtained from its solution, the most direct inference certainly is, that oxymuriatic acid is a compound of muriatic acid and oxygen: but in applying this doctrine to other instances, as to that of the direct union of oxymuriatic acid and hydrogen, it is necessary to assume that some changes happen, of which there is not any independent proof, such as the deposition or the formation of water. If, on the other hand, we look only to the experiment of the mutual action of oxymuriatic acid and hydrogen, the most direct conclusion is, that they simply combine; but in extending this theory, it is in a great number of instances necessary to assume the decomposition and recomposition of water, and other changes, for which there is not the slightest evidence. These suppositions are not always required in the two systems in relation to the same fact; but still, where an hypothesis is required in the one, a corresponding hypothesis will in general be required in some part of the other. They occur even more frequently on the new doctrine, particularly in its application to the salts of muriatic acid, which are conceived to undergo the most complete changes on the addition or abstraction of water without the smallest indication of the occurrence of such changes being discernible. When solutions of protonitrate of mercury and muriate of soda, for instance, are mixed together, nitrate of soda and calomel, it is known, are formed; by all the usual rules of inference from the decompositions of neutral salts, we should conclude, that the acids had exchanged bases,—that the nitric acid had united with the soda, and the muriatic acid with the protoxide of mercury; but the inference is very different on the new view, that the muriatic acid and oxide of mercury have decomposed each other, and that a metallic chloride is formed, in no respect analogous to a salt: Is there nothing hypothetical in this explanation? Are the changes supposed to happen in this instance apparent, or are they similar to what happen in other cases? Still, it is not denied that there are also various explanations of facts in the old view which are not supported by any actual proof. Such being the case, it is a mere sophism to select those parts of the one doctrine in which the induction appears direct, to affirm that these demonstrate the



truth of the opinion, and to regard the assumptions necessary in the farther application of the doctrine, as necessarily following from it ; but to pursue the reverse method with regard to the other,—to represent it as an hypothesis, by bringing forward the parts which require assumptions, and neglect or reject the more direct inductions on which it is founded.

It has been objected to the old theory, that muriatic acid gas has not been proved to contain water. If it were, there would be an end of the discussion. In comparing the merits of two opposite views of a subject, what argument is it to object against one of them, that its truth has not been demonstrated? if it was, there could be no farther comparison. The real question is, whether there are not probable grounds for inferring its existence in the gas, and whether the experiments in which it is partially procured are correct or not? The farther statement which has been made, that chemistry is a science which requires every step to be demonstrated, admitting no substance to be a compound unless it is proved to be so, is one equally unfounded ; for there is not a single fact in the science which admits of demonstration ; chemistry professes only to draw the most probable inference from observed phenomena.

To decide the question respecting the nature of chlorine, remarks Berzelius, it will, no doubt, be necessary to produce the real base in a separate state. At present this is not possible. But, how can it be fairly concluded from this, that such a decomposition may not hereafter be effected? and how can such a circumstance be objected, as a decisive proof against the old doctrine? Prior to 1806, it might have been asserted, that the fixed alkalis were simple bodies, and that the inference of Lavoisier, from analogical reasoning, that they were oxides, ought to be rejected, as contrary to the principles of chemistry. We now know, that such an assertion would have been erroneous, although it could not be refuted so completely by reasoning, as by the actual result of the decomposition of the alkalis. Boracic acid presents another instance precisely similar to that of muriatic acid. These examples may be applied to the present philosophy of the supporters of the new doctrine, as they, disclaiming all analogy, require the reduction of muriatic acid as the only thing capable of refuting the new doctrine.



In 1806, we were not aware of the reducing power of Davy's electrical apparatus; and who, at present, can estimate the energy of an electrical battery, a thousand times greater in all dimensions than those which he employed? Though it is not in our power, then, at present, to establish our position by experiment, it ought not to be permitted, in chemical philosophy, to build any thing on this impossibility; nor lay aside, as false and absurd, what appears exceedingly probable in other points of view; and, because it is not in our power to allege positive experiments, to affirm that our opinions are destitute of all positive evidence. We surely should take such views of the subject, that posterity will rather confirm than refute our present conjectures. This can only be done by carefully studying analogy, and confining ourselves to conjectures which are conformable to those parts of chemistry which may be considered as established. Whoever lays hold of a particular phenomenon, and considers every thing else, how probable soever, provided it be not established by actual experiment, as inaccurate, merely that he may establish a new hypothesis, however little it may accord with the rest of chemistry, is in danger, that some other chemist shall be more fortunate than he in his view of the phenomenon, and that posterity shall consider him, not without justice, as short-sighted in his views. Such are the judicious remarks of Berzelius.

In fact, the maxim of admitting no substance to exist unless it has been obtained, and of allowing no inference from analogy with regard to the composition of bodies, is one so totally at variance with the general principles of chemistry, that it is little attended to in other parts of the science, and by none is it so frequently violated as by the advocates of the new theory. There cannot be a plainer instance of this than that of the imaginary substance, Fluorine, which has never been procured, and of the existence of which there is no evidence, being uniformly affirmed to be the base of fluoric acid, and placed in the same class with oxygen as an electro-negative agent, and a supporter of combustion. Even if fluoric acid could be separated into hydrogen, and a distinct substance, that substance might be a compound of fluoric acid and oxygen, and the result would still be ambiguous; but when no such result



has ever been obtained, can there be a clearer example of arbitrary and unsupported hypothesis? Is this the manner in which the *just logic of chemistry*, which is held forth as the foundation of the new doctrine, is to be applied to phenomena? The siliceo-fluoric acid is an equally singular instance. It has, for many years, been supposed, by the supporters of the new view, to be a compound of fluorine and the metallic base of silex; yet it is only of late that the latter has been obtained, and the former not at all.

But to take other examples of more importance. What proof is there of the existence of real nitric acid? Who has ever obtained it, or examined its properties? It is as utterly unknown to us as real muriatic acid; and the supposition of its existence ought equally to be rejected by the advocates of the new theory. It may be said that it exists in its salts; but who shall decide in what state the elements of a salt are arranged? If the supporters of the new doctrine wish to be consistent, they ought to adopt Dr Murray's view of the nature of the stronger acids, that the water supposed to exist in them is not adventitious, but forms an integrant constituent of them; that nitric acid, for instance, is a ternary compound of nitrogen, oxygen, and hydrogen, not a compound of an unknown hypothetical substance, called real nitric acid, with water. The same remark applies to what are supposed to be real oxalic, chloric, tartaric, citric, and other more powerful acids; likewise to the hypo-sulphurous, hypo-sulphuric, hypo-phosphorous, hypo-nitrous, ferrocyanic acids, &c. In like manner, the earths have, for many years, been admitted to be all compounds of metallic bases with oxygen, though, with regard to several of them, this conclusion has been formed in a great measure from analogical reasoning, the experimental results respecting them being too imperfect of themselves to establish the inference.

Some analogies have been brought forward in support of the new doctrine, but which are, in reality, extremely adverse to it. Thus, it is urged, that sulphuretted hydrogen and prussic acid are acids formed, like muriatic acid, by the union of hydrogen with a base; but what resemblance, it may be inquired, has muriatic acid to these feeble acids? Is it not in taste, density, power of affecting colours, and when concentrated, of corroding and blackening animal and ve-



getable substances, in the facility with which it dissolves earths and metals, in the characters of its salts, in their permanence, in the force of affinity existing between their elements, strikingly similar to the acids which contain oxygen? No reason can be assigned, as is remarked by Berzelius, except the necessity of the new doctrine, for classing muriatic acid with such substances as sulphuretted, phosphuretted, arsenuretted, and telluretted hydrogen, or with prussic acid, rather than with nitric and sulphuric acids.

Iodine is supposed to present an instance of a substance precisely analogous to chlorine, and this analogy, it appears, has had much effect in favouring the reception of the new view. But, in fact, there is very little analogy between them; and the real circumstance relative to iodine which has favoured the new doctrine is, that it was first examined by supporters of that doctrine, and its properties and combinations expressed according to the principles and in the language of the new view. Hence the old view has never been applied to it, though as capable of explaining all the phenomena, and with fewer assumptions. Iodine has, in truth, a much greater analogy to a metallic oxide than to oxygen. Chlorine and iodine, remarks a supporter of the new view, "differ from oxygen, in both of them forming acids with it, very similar to the "nitric:" this is certainly not a slight distinction.

The single circumstance of the high combining weights of chlorine and iodine has always appeared to me nearly a demonstration of their compound nature. It is a character not liable to be disguised or mistaken, and which can be ascertained without any ambiguity; and it is a rule without exception, that the equivalents of simple non-metallic bodies are comparatively small, yet the equivalent of chlorine exceeds the equivalents of all simple bodies except metals, and that of iodine exceeds even the equivalents of almost all the metals.

A striking similarity, it has been pointed out by my Father, exists between oxymuriatic acid and sulphurous acid. Their combining weights are nearly the same, that of the former being 36, and that of the latter 32, and there is an equally strong resemblance between these bodies in properties; they are both gaseous, and their specific gravities are nearly the same; they have both a pe-



cular suffocating odour, both destroy instead of reddening the vegetable colours, can both of them be reduced by strong pressure to the liquid form, are nearly equally soluble in water, and remain combined with it in congelation; there is little difference in the degrees of their acidity, and they both pass to the positive pole of the voltaic series; there are scarcely any two bodies which agree in so many circumstances. If the old doctrine be adopted, that they are both compounds of inflammable bases of similar characters, all these circumstances are exactly such as might be expected, and any difference between them is precisely what should happen from the excess of oxygen in oxymuriatic acid. On the new view, there ought not to be a single point of agreement. There is also a considerable resemblance between chlorine gas and nitrous acid vapour, in being both coloured, both having an irritating odour, both destroying contagion; and this similarity accords with the old doctrine, for the equivalent of murion is not far from that of nitrogen, and nitrous acid contains only an additional atom of oxygen. Instead of such obvious analogies, chlorine is considered by Gay-Lussac as analogous to sulphur; but in what the resemblance consists, it is difficult to discover.

It is of course denied, on the new hypothesis, that oxymuriatic gas is an acid; yet there are many other substances admitted into the class of acids with much less title to that character. If it is objected that it does not redden but destroys colour, the same remark applies to sulphurous acid; oxymuriatic acid combines with alkalis and earths, forming neutral compounds, the saline nature of which has been clearly proved by Berthollet, Mr Dalton, and Mr Wilson. It is true that the alkaline oxymuriates cannot be obtained in the dry state, but this is owing to their tendency to be resolved into muriates and hyper-oxymuriates. Nitrous acid is now generally admitted to be an acid, but scarcely a single salt of it can be procured, from its having an exactly similar tendency to be resolved into nitric oxide and nitric acid. The acidity of oxymuriatic acid is sufficiently proved by its compound with lime, though there were no other proof.

The fact of chlorine not uniting with charcoal at high temperatures, has been already noticed as a difficulty on the new view, but



conformable to the old doctrine. Dr Davy attempted to answer this objection by the following question: Can Mr Murray account for the want of action between charcoal and nitrogen, and between the metals and nitrogen? and if he cannot, does he consequently consider these facts anomalous? The fallacy of such a reasoning, as Dr Murray remarked, is obvious. Nitrogen acts upon none of the inflammables, nor is there any principle on which it should be inferred to act upon them. But, on the new view, chlorine is held forth as an energetic agent, a supporter of combustion, and even an acidifying principle analogous to oxygen, and it is found to act on other inflammables; it is, therefore, an anomaly, for which no reason is assigned on the new doctrine, that it has not the slightest action on a substance of such ready combustibility as charcoal. The anomaly is still greater, as Mr Faraday has shown, that by indirect means substances containing chlorine and carbon can be procured: why then do they not directly unite?

It was regarded by Sir H. Davy as a proof of the truth of his opinion, that when oxymuriatic acid combines with a base, the quantity of oxygen evolved is always equal to that in the base; the doctrine of equivalent quantities at once shews the fallacy of such an argument; for exactly the same quantity of oxygen will, on the old theory, be liberated from the oxymuriatic acid. The constitution of muriatic acid and its compounds, on the old view, may be stated as follows: This acid is supposed to consist of an inflammable base, *murion*, as my Father proposed to name it, from the analogy of carbon and boron; the equivalent of this radical may be inferred to be 12, or the same with that of phosphorus; dry muriatic acid consists of one atom of murion, 12, and two of oxygen, 16; hence its atomic weight is 28; in composition, and in its equivalent, it is thus similar to dry phosphoric acid: if we add to it an atom of combined water, 9, we obtain 37, the equivalent of muriatic acid gas, which is the same with that of hydro-phosphoric acid. If instead of an atom of water, an atom of oxygen, 8, is added to real muriatic acid, the resulting equivalent is that of oxymuriatic acid 36. Now, when oxymuriatic acid acts on a protoxide, as that of lead, an atom of oxygen is evolved, which Sir H. Davy supposes to come from the metallic oxide, but on the old



doctrine is inferred to come from the oxymuriatic acid, which becomes muriatic acid, and unites with the oxide of lead ; and the one explanation is as probable as the other.

It has been stated by several able chemists, as a reason for their adopting the new doctrine, that it affords the best basis for an arrangement of the objects of chemistry. Accordingly, substances have by some been divided into two great classes, of electro-negative and electro-positive ; oxygen, chlorine, iodine, and the imaginary substance, fluorine, being placed in the first class, and all other bodies, simple or compound, in the second. It is surprising that so unphilosophical an arrangement should ever have been proposed. The character of a body of passing to the positive pole of a galvanic apparatus is merely relative, depending upon the other substance with which it is associated ; chlorine and iodine, it is true, are electro-negative with regard to other bodies, but they are electro-positive when united with oxygen. With respect to fluorine, there is no proof, that if it exists, it is more highly electro-negative than many other substances. Nor in this arrangement is any reason given for limiting the first class to four bodies : it might equally include sulphur, and the other inflammables, and might in fact, with as much propriety, include all known substances. It would be as philosophical to divide all bodies into two classes, one of *heavy* bodies, and the other of *light* bodies, and to place the four heaviest of the metals in the first class, and every other substance in the second.

As has been remarked by Berzelius, chlorine in fact presents a contradiction to the electro-chemical theory of Sir H. Davy. Chlorine, we are told, expels oxygen from potash, and must hence have a stronger affinity for potassium, or, in the language of the electro-chemical theory, it destroys the electro-chemical properties of potassium more completely than oxygen, and hence must be more electro-negative than that element. But when euchlorine and chloric acid are decomposed by galvanism, the chlorine passes to the negative pole, proving that it is less electro-negative than oxygen, chlorine is therefore naturally more, and at the same time less electro-negative than oxygen, which is a direct contradiction in terms. Either the electro-chemical theory, or the new doctrine



of the nature of chlorine must therefore be false; on the old view there is no difficulty whatever.

It is a remarkable circumstance, observes Berzelius, that chlorine, an elementary body, should be so similar to its first compound with oxygen, euchlorine, in colour, smell, solubility in water, &c. that for many years they were not distinguished from each other. This fact is unfavourable to the new opinion; for it is reasonable to suppose that two so similar bodies are contiguous oxides of the same base.

It has been remarked, that no simple substance forms a crystallizable compound with water; yet hydrate of chlorine can easily be obtained in regular crystals. It may also be observed, that chlorine was reduced by Mr Faraday to the liquid form, which could not be effected with a single gas acknowledged to be simple.

Chlorine combines with phosphorus, and forms two compounds, which unite with ammonia in definite proportions. On the old theory the combinations are supposed to be double salts, of muriate and phosphate or phosphite of ammonia, free from water; but in what light are they to be considered on the new view? Chlorine does not itself combine with ammonia, neither does phosphorus; are the chlorides of phosphorus to be regarded as acting the parts of acids, and if they are, what singular acids they must be, which only unite with one base, and only form one salt? The chloro-carbonic acid as it is termed, is said to exhibit strong acid powers, yet it too presents the extraordinary anomaly of combining with only one base, and forming only one salt. The permuriate of tin, (or bichloride of the new doctrine,) absorbs ammonia, and forms a solid substance very like a salt; dry muriate of lime, (chloride of calcium,) also absorbs ammonia, which remains in a state of combination. On the old view, these are of course regarded as triple salts free from water; and as ammonia has a peculiar tendency to form triple salts with other acids and bases, there is not the slightest improbability in this opinion. But what are the compounds conceived to be on the new hypothesis? There is no nitrogen evolved; therefore the ammonia yields no hydrogen to the chlorine to convert it into muriatic acid; and even if it did, there is no oxide for that acid to unite with. The constituents on the new view are simply chlorine, ammonia and metallic tin or metallic calcium: does



the tin or calcium form a salt with the ammonia ? or is it supposed, that chloride of tin and chloride of calcium are acids ; and that these singular acids are, like the chloro-carbonic, distinguished by the peculiarity of combining only with one substance, and never forming but one salt ?

“ The embarrassment,” says Berzelius, “ into which the supporters of the new doctrine are thrown when they speak of muriates, may provoke a smile. They neither agree with each other, nor with themselves, about what to consider as muriates, “ what chlorides.” In reality, muriatic acid, though admitted by all to exhibit the properties of a powerful acid, is supposed, on the new theory, to form only one dry salt, muriate of ammonia, and a few salts of little permanence, as the muriates of alumina and magnesia. It used to be supposed, however, that muriates existed when in solution ; and although the alleged transformations of chlorides into muriates by being dissolved, were wholly hypothetical and improbable, yet this supposition gave a species of analogy, though a limited one. Partial as it was, it yet has not been maintained ; and the opinion is now held by many of the advocates of the new doctrine, that a number of the chlorides, as those of gold, platina, and mercury, dissolve in water without change : the alkaline and earthy chlorides, again, are affirmed to be changed into muriates ; and there is a third class, including chlorides of cobalt, copper, nickel, and some others, regarding which, we are told, it is quite uncertain in what state they exist when in solution. Is the change slight, which thus so easily escapes notice, that it cannot be known whether it has occurred or not ? on the contrary, it is no less than the conversion of a substance similar to a metallic oxide, containing neither acid nor alkali, into a neutral salt containing both. In such uncertainty and ambiguity does the supposed simple doctrine of chlorine involve even the plainest phenomenon, the mere solution of dry salts in water.

Besides the improbability of the mysterious transformations of muriates into chlorides, and *vice versa*, they do not accord with the laws of affinity. To take the instance of muriate of potash, which is supposed to exist as a neutral salt when in solution : Oxygen, it is known, has a very powerful affinity to potassium, and chlorine has a strong affinity to hydrogen ; oxygen has also some



attraction to chlorine, and hydrogen has an affinity of considerable force to potassium; yet these four affinities are conceived, on the new doctrine, to be completely overcome by the application of a gentle heat, or by the mere act of crystallization; a supposition, certainly, in the highest degree improbable. The same remark applies to the imagined conversion of the muriates of soda, lime, barytes, &c. into metallic chlorides.

Apparently aware of the improbability of their view of the nature of salts, and of the inconvenience of giving two names, and ascribing two natures to compounds which, by every common rule of judging, appear to remain in all states the same; the supporters of the new doctrine very frequently reject scientific appellations, and have recourse to arbitrary names, which it might have been expected would have been long since banished from chemistry. Hence, we read of common salt, bleaching powder, calomel, corrosive sublimate, butter of antimony, butter of zinc, fuming liquor of Libavius, aqua regia, &c.—a nomenclature certainly opposed to every idea of scientific precision. It is, in fact, almost impossible to describe the salts of muriatic acid on the new view without frequent contradictions. To say, for instance, that a crystal of *chloride of sodium* has a saline taste, is on this view incorrect, for it is muriate of soda which gives the taste. To say, on the other hand, that a crystal of *muriate of soda* has a saline taste, is equally improper; for the crystal is not muriate of soda, but chloride of sodium. To escape this dilemma, the substance is called *common salt*; but this is even a more unfortunate term than the others, for the substance is neither a salt, nor in any respect analogous to a salt.

There are numerous other objections which, if the limits of this work would permit, might be stated against the new doctrine of Gay-Lussac and Sir H. Davy; they will be found in my Father's papers in Nicholson's Journal, (vols. xxviii. xxxiv.) and in vols. vii. and viii. of the Annals of Philosophy. On looking back to those which have been here stated, it will appear that not one of them applies to the old opinion, nor has any fact ever yet been brought forward which it has not perfectly explained. The experimental evidence in favour of the latter may now be examined.



The first experiments performed by Dr Murray had for their object to obtain carbonic acid from mixtures of oxymuriatic acid, carbonic oxide, and hydrogen gases, inflamed by the electric spark, or exposed to the action of light, the last of these gases being added, that it might favour the production of muriatic acid. The constant result which he obtained was the disappearance of a considerable portion of the carbonic oxide; and when the whole was condensed by the introduction of ammonia, the salt obtained, he found, effervesced on being thrown into nitric acid, from the disengagement of carbonic acid. These statements were at first denied, and attempted to be invalidated by some very singular controversial methods, for the particulars of which, it may be sufficient to refer to the papers of Dr Murray, Dr Davy, and Sir H. Davy, in Nicholson's Journal. Finally, the accuracy of Dr Murray's experiments was fully admitted. Repeating his experiment on the exposure of the three gases to light, Dr Davy stated, that after the addition of ammonia, he could detect "no traces of carbonic oxide;" and, on throwing the salt into nitric acid, "perceived an effervescence," which effervescence, he also admitted, was owing to carbonic acid. These were the precise results which Dr Murray had always obtained, and which had been before denied.

This experiment by Dr Murray appears to be very unfavourable to the new theory. It is attempted to be accounted for by supposing a peculiar acid gas, the chloro-carbonous, to be formed, which unites with the ammonia, and, when the salt is decomposed by nitric acid, this gas is supposed to decompose water, and be converted into carbonic and muriatic acid. All this reasoning is hypothetical; there is no proof that this gas is produced when hydrogen is present, nor, if it is, that it is instantaneously converted into carbonic and muriatic acid; the contrary might be inferred from Dr Davy's statement, that it is slowly absorbed by water. If oxymuriatic acid and carbonic oxide do form a condensed compound, the opinion is a more probable one, that it is a murio-carbonic acid, or double acid of dry muriatic and carbonic acids, than that it is a new and peculiar acid which forms only a single salt. The supposition of a compound acid is one which there can be little difficulty in admitting, as there are analogous instances in the fluo-boric acid,



the fluo-chromic acid, the compound acid of hypo-sulphurous and nitrous acids discovered by Dr Henry, and various others ; it may also be remarked, that a definite murio-carbonate of lead exists in the mineral kingdom. On the other hand, there is not a single parallel instance to the chloro-carbonous acid of the new theory.

Another experiment by Dr Murray was that of converting sulphuretted hydrogen into sulphuric, or sulphurous, (or perhaps rather hypo-sulphurous) acid, by the action of a large proportion of oxymuriatic acid. In opposition to his results, it was stated, that when the mixture is condensed by ammonia, the salt formed consisted of muriate of ammonia, and a compound of ammonia and oxymuriate of sulphur. Yet it is known, that oxymuriate of sulphur does not unite with ammonia, but decomposes it.

The third series of experiments performed by Dr Murray were still more important, and less liable to ambiguity. Their object was, as has been stated in the text, to obtain the combined water, inferred on the old doctrine to exist in muriatic acid gas, by uniting this acid gas with dry ammoniacal salt, and heating the salt produced. It is admitted, that if water is obtained, it decides the question in favour of the old doctrine ; and it was obtained in larger or smaller quantity in all the experiments performed by Dr Murray, in those of Dr Bostock and Dr Traill, in those executed in the presence of Dr Hope, and in all the experiments of Sir H. Davy and Dr Davy, except the first which they made, in which, as in the instance of carbonic oxide, it was denied that any appearance of moisture could be perceived. The advocates of the new doctrine, unwilling to give up their opinion, have brought forward every objection that could be imagined against these results ; and yet, what is highly in their favour, with all the precautions, and in all the forms in which the experiment has been executed, there has not been an instance, ever since its importance was appreciated, in which a portion of water has not been procured, rendering, of course, assumptions necessary on the new doctrine, to account for the result.

Of these, the first, and one justly termed by Dr Murray an extravagant assumption, was, that the salt absorbed water hygrometrically, like any loose powder. Can it be seriously believed, that



in a dry atmosphere, a small quantity of a powder which is not deliquescent, will, in the course of two or three minutes, absorb nearly a grain of water? If it is from chemical affinity that it imbibes this portion of water, why does it not attract more till it deliquesces? and why, if its attraction to moisture is exerted with such rapidity and such force, does it so easily again give out this humidity, on the application of heat? How does it happen, too, that this water, condensed in distinct globules close to the sublimed salt, is not re-absorbed by it even after 24 hours? The experiments performed by Dr Murray and Dr Hope, of exposing the fresh salt for many minutes to the air, in a balance, when it did not in the slightest degree increase in weight, are a sufficient refutation of this singular objection. Dr J. Davy admitted, that when the experiment was performed in the manner employed by Dr Murray, of forming the salt in one vessel, and then transferring it to a retort, and heating it, "water in no inconsiderable quantity was evolved:" this he ascribed to the absorption of moisture: but since the fallacy of such an opinion has been demonstrated, the admission is one of some importance, in confirmation of Dr Murray's results.

It was next affirmed, that the water must be derived from hygrometric vapour in the gases, a supposition as improbable as the former. It will be seen, by referring to the account of Dr Murray's experiments, (*Nich. Journ.* vol. xxxiv. p. 267, and *Edin. Trans.* vol. viii, p. 287,) that the greatest care was taken in employing the gases thoroughly dried; and when used in this state, the researches of Dr Henry and others have proved, that no watery vapour exists in them. Indeed, is it to be supposed, that in a gas in which the fluoboric acid, the most delicate test of humidity, produces no cloud, such a quantity of water shall yet exist, as may be obtained in numerous distinct globules?

The small quantity of water procured from muriate of ammonia, by applying heat to it, much less than what on the old doctrine it is calculated to contain, has frequently been objected to the results obtained by my Father. But, as he remarked, of all the salts of muriatic acid, the muriate of ammonia is the one from which it might be expected to be most difficult to abstract the water, as it is volatile, and readily decomposed; the ammoniacal salts in general, too, retain the water which exists in them with much force, and no other



base can in this case be introduced to separate the acid, as it would render the result ambiguous. He made the experiment, to prove the *existence* of water, not to estimate its *quantity*: the quantity can be ascertained with perfect precision from other salts; but with them there is an ambiguity, from their bases containing oxygen. Dr Thomson will not admit the existence of water in muriate of ammonia, because an entire atom was not expelled from it by heat; but on this ground there are few salts respecting which the presence of part, or often of the whole of the water known on other grounds to exist in them, might not be denied. For of the whole number of salts, more than two-thirds, and, amongst these, all the ammoniacal ones, refuse to part with all the water which they contain, at the temperatures of  $400^{\circ}$  or  $500^{\circ}$ ; there are many salts which suffer no loss of weight whatever at these temperatures, but at a red heat yield a considerable proportion of water, and some require a very intense heat to expel it. From this circumstance, the water present in salts can in very few cases be estimated by expelling it by heat: it is, therefore, quite unreasonable to expect that this should be effected with muriate of ammonia.

Berzelius has objected to Dr Murray's results on a truly hypothetical principle. He imagines that no neutral ammoniacal salt can exist without water; and on this supposition affirms, that no water ought to be obtained from the muriate. This singular objection has been fully refuted by Dr Murray, (Edin. Trans. vol. viii. p. 295.) It is a well-known fact, that when acids containing combined water unite with bases, the water becomes no longer essential to the constitution of the salt, and hence by a sufficient heat it can be entirely expelled; and there is no principle on which it can be inferred, that ammonia should be different from other bases. The instance, moreover, of carbonate of ammonia pointed out by Dr Murray, is of itself a sufficient proof of the inaccuracy of Berzelius' assumption; for that salt consists, like the muriate, of exactly one atom of acid and one atom of ammonia, and yet contains no water; the alkaline properties, indeed, are not so completely neutralized in it, but this is from the weak acidity of carbonic acid, not from any deficiency in its proportion. The objection is thus, as Dr Murray remarked, "unfounded, and ought not to have



“ been brought forward on mere speculation against a positive result.” It might have been expected that so able an experimentalist as Berzelius would have repeated the original experiment, to convince himself whether the supposed sources of fallacy were adequate to account for the result; instead of which, he is satisfied by affirming it to be impossible on a theoretical principle of his own; and having thus set aside the strongest evidence that has yet been brought forward in support of the old doctrine which he then held, it is the less surprising that he should have since adopted a modification of the new views. The modification which he has adopted is certainly a singular one, and nearly as much opposed to the one doctrine as to the other. The muriatic acid, which, it cannot be denied, exhibits every character of a powerful acid, does yet, according to Berzelius, not form a single salt, all its compounds being chlorides, whether dry or in solution, (Ann. of Phil. N. S. vol. x. p. 184.) The muriate of ammonia might be supposed to present some difficulty to this opinion, as every supporter of the new doctrine has admitted it to be a salt. An altogether new view of its nature, however, is given by Berzelius, namely, that the hydrogen of the muriatic acid combines with the ammonia, forming *ammonium*, (vol. ii. p. 9,) and that this *ammonium* combines with the chlorine. By this curious verbal distinction, sal-ammoniac is converted into a *chloride of ammonium*, and is thus conceived to be rendered analogous to the metallic chlorides. No evidence whatever is given of this supposed conversion of ammonia into a substance, the existence of which is scarcely admitted by chemists. Though the changes supposed on the doctrine of chlorine to happen in bodies are certainly often sufficiently mysterious and singular, it has no proposition so extraordinary as this.

The last series of experiments performed by Dr Murray were those in which muriatic gas was passed alone over ignited metals, when, from the formation of super-muriates, a quantity of water was procured; this was equal to between a fourth and a fifth of what is inferred on the old doctrine to exist in the acid gas. Zinc-filings were chiefly used, which are peculiarly adapted to the experiment, as the muriate of zinc appears to unite readily with different portions of acid, so that it can scarcely be obtained of de-



finite composition ; iron-filings also were used. The quantity of water obtained was not far from what might have been expected, a considerable portion of the water being consumed in oxygenating the metals, and probably only a part of the muriates produced being converted into super-muriates. The experiments thus made seem to be free from every source of fallacy, and their result was successful. Two new objections, however, have been made by Sir H. Davy, (Phil. Trans. 1818, p. 169) ; the first, that atmospheric air must have been present in the tubes ; the second, that the water must have been derived from the oxide of lead in the glass ; and he has stated some experiments in proof of these assertions. The futility of these objections has been shewn by Dr Murray, and is obvious on referring to the account of the experiments. In that which was most decisive, and of which, though it is the one most fully described, Sir H. Davy has taken no notice, a retort was used instead of tubes ; the atmospheric air was expelled from it, and during the whole experiment it was kept full of muriatic acid and hydrogen gases, the air being excluded ; the heat applied was by a lamp, and was much inferior to a red heat ; the part of the retort too that was heated was the bottom, which was covered with metallic filings, so that there is not the slightest reason for supposing any decomposition of the oxide of lead in it : from the high combining weight of oxide of lead, it would be necessary to suppose, that to produce a grain of water, above *twelve* grains of oxide of lead must have been completely decomposed, and yet the glass exhibited no signs of corrosion.

My Father simply replied to the objections which Sir H. Davy had made to his experiments ; but on examining carefully the memoir of the latter distinguished chemist, I have observed a detailed account of a very extraordinary experiment. The following is the description of it : “ I have shown,” says Sir H. Davy, “ that  
“ in the action of muriatic acid upon metals, hydrogen equal in  
“ bulk to half the volume of the gas is produced ; it is therefore  
“ evident, that if water had been generated by the action of muriatic acid on metals, it must have been the *chlorine*, or the *metal*, or both, that were decomposed. As chlorine can be freed  
“ from much of its aqueous vapour by dry muriate of lime, which



“ is not the case with muriatic acid gas, it offers a much more un-  
“ exceptionable substance for experiments of this kind. I passed  
“ 23 cubical inches of chlorine slowly through dry muriate of lime  
“ into a flint glass tube red hot, containing a green glass tube full  
“ of iron wire ; the chlorine combined with this iron wire with in-  
“ tense heat ; the bright sublimate formed was passed through  
“ more iron wire heated to redness, so as to form a considerable  
“ quantity of the first compound of chlorine with iron, which, when  
“ examined, was found exactly the same as that produced by the  
“ action of muriatic acid gas on iron. All the products were heat-  
“ ed strongly, and the end of the glass tube kept very cool, but  
“ *not the slightest appearance of moisture was perceptible.* In  
“ these experiments I was assisted by Mr Faraday of the Royal  
“ Institution.” From the care with which the above experiment  
appears to have been performed, and from the emphatic manner in  
which its result is stated, it seems to have been regarded by Sir  
H. Davy and Mr Faraday as one of much importance, and as de-  
cisive against the experiments of my Father. It may be sufficient  
merely to inquire, on what principle it was expected that water  
should appear ? Chlorine or oxymuriatic acid, according to the  
old doctrine, contains a large proportion of oxygen ; but from whence  
was the other constituent of water, hydrogen, to come ? Muriatic  
acid gas was employed by Dr Murray, because it is inferred to con-  
tain combined water ; but he never certainly attempted to procure  
water from chlorine. It is plain that this experiment was not made  
to detect hygrometric water ; for it is assumed that the chlorine was  
in a great measure free from it : it was obviously performed as a  
parallel experiment to Dr Murray’s, substituting chlorine for mu-  
riatic acid gas,—an unfortunate substitution, as from the absence of  
hydrogen no water could ever appear, and thus the two excellent  
chemists, by whom the experiment was executed, laboured with  
much care to obtain an impossible result,—impossible either on the  
old or the new doctrine, or on any view that has ever been given of  
the subject. In short, the mistake is an obvious one, and it is only  
remarkable that it was not perceived in performing the experiment,  
nor in subsequently giving an account of it. Is it allowable to  
remark, that this is perhaps an instance of the hasty manner in



which the arguments and experimental results, brought forward in support of the old doctrine, have been usually attempted to be answered ?

Setting aside its erroneous object, this experiment of Sir H. Davy and Mr Faraday appears to be much in favour of the old doctrine. For muriatic acid gas can be freed more completely than chlorine from hygrometric vapour ; as from its not acting on mercury, it can be kept for many hours exposed to dry muriate of lime, which cannot easily be done with chlorine. The reverse of this is, indeed, supposed by Sir H. Davy, but he has given no reason for his opinion. Now, the chlorine, it appears, though merely passed through a tube containing muriate of lime, did not deposit the smallest quantity of moisture ; therefore muriatic acid gas, which has been kept in contact with dry muriate of lime for twenty-four hours, certainly ought to deposit no water ; and since it actually does yield water, this must be derived from its composition, not from hygrometric vapour. The experiment thus fully confirms those of my Father. It would appear, from the manner in which Sir H. Davy gives the rationale of the experiments communicated to the Royal Society of Edinburgh, that he was not aware of the mode in which Dr Murray explained the results, namely, by supposing (indeed proving) that super-muriates are formed ; hence his explanation is imperfect, and in it likewise the hydrogen of the acid gas is overlooked.

Such are the experimental results which were obtained by my Father, and such the objections which have been made to them ; it is difficult to conceive how the latter could be proposed, and how they can still be maintained. In the whole history of chemistry, there is, perhaps, scarcely another instance in which the rules of Bacon's logic, and the common principles of estimating scientific evidence, have been more plainly violated, than in the manner in which my Father's experiments have been replied to. It is the boast of modern philosophy, that so implicit and unhesitating is its submission to facts, that should a single experimental result be directly opposed to a theory, however ingeniously that theory may be framed, and however plausibly it may explain the phenomena to which it is applied, it must be immediately abandoned ; but how



little has this maxim been attended to in the present question? Had there been no hypothesis to defend, the result of so many experiments, in which water has been uniformly obtained from muriatic acid, would long since have been fully admitted; but because this result is incompatible with the hypothesis, every objection however improbable that could be imagined has been successively opposed to it. At one time it was the absorption of hygrometric moisture, at another hygrometric vapour in the gases. These assumptions not appearing sufficient to support the doctrine, it was next affirmed to be atmospheric air in the apparatus; and, lastly, to be derived from the oxide of lead in the glass. In what other experiments are there such various and insurmountable impediments to accuracy? and what results on other subjects are contradicted on such grounds? One chemist refuses to believe the result of numerous and careful experiments, because it contradicts an opinion that he has adopted, that ammoniacal salts cannot exist without water: Others reject it, because the whole water is not obtained from the salt by heat, though from no other salt of the same class is the whole water separated by heat. Is such reasoning to be admitted as valid in chemistry? And, after all, for what are these violations of consistency, and of scientific logic, incurred, but to defend an hypothesis at variance with all the most strict and extensive analogies of the science, and which, in its application to phenomena, assumes changes to happen in bodies, for which no evidence can be given, either by our senses, or by the common methods of scientific investigation? ED.

An account was given in the first volume, (p. 499.) of Dr Murray's views relative to acidity. It would appear that some speculations have been lately proposed by Dulong, which, as far as they have been carried, agree closely with those of Dr Murray. The following is the account of them given by Berzelius: "Dulong has attempted to reconcile the inconsistency between the compounds of acids containing oxygen and of hydracids, by regarding all acids which contain water as hydracids. He joins the oxygen of the water to the acid, and forms with the radical of the acid and its



oxygen a compound radical, which, in union with the hydrogen of the water, constitutes the hydracid. Thus he regards hydrous sulphuric acid as a compound of hydrogen, with a radical composed of one atom of sulphur and four atoms of oxygen; that is, containing one third more of oxygen than is considered to exist in sulphuric acid. When this acid combines with a metal, potassium, for example, hydrogen only is disengaged, and the potassium combines with the compound radical of the hydracid. The sulphate of potash thus formed, ought to be regarded as a compound not of sulphuric acid and potash, but of potassium and the radical of the hydracid, (that is, sulphur, with the whole quantity of oxygen, constituting a single integrant particle.) This explanation of Dulong's is unquestionably entitled to considerable praise; because it re-establishes the harmony in the doctrine of salts, which had been disturbed by the nature of muriatic acid, and indeed to a still more general extent, by the phenomena accompanying the combinations of hydracids."

On comparing these speculations of Dulong, which are so highly approved of by Berzelius, with the statement of Dr Murray's views, their agreement will be obvious. The opinions, that the combined water is an essential ingredient of many acids, that these acids consist of radicals combined with oxygen and hydrogen, that from adding the oxygen of the water to that formerly estimated to exist in the acid, the quantity of oxygen, on this view, existing in the acid, is increased by one atom, hydro-sulphuric acid, for instance, being regarded as containing four atoms of oxygen, instead of three, as usually supposed; lastly, that the neutral salts are composed of the radical of the acid and that of the base with a quantity of oxygen equal to what existed in the hydrous acid, are exactly the same with those of Dr Murray. Sulphate of potash, for example, is conceived by Dulong to consist of sulphur, potassium, and the four atoms of oxygen that were present in the hydro-sulphuric acid, and this is the precise constitution ascribed to it by Dr Murray, (vol. i. p. 506.) It thus appears, that the speculations of Dulong, though they are not founded on such enlarged general principles as the views of Dr Murray, yet to the extent to which they are carried, are essentially the same with the latter, published seven years before.



## TABLE OF AFFINITIES.

OXYGEN.	Antimony	Carbonic	Saccho-lactic	Magnesia
Metallic bases	Quicksilver	Prussic	Succinic	Ammonia
of the alkalis	Arsenic	Sulphur	Nitric	Argil
and earths.	Molybdenum		Muriatic	Metallic oxides
Carbon	Tellurium	STRONTITES.	Tartaric	
Manganese		Acids	Citric	SULPHUROUS
Zinc	AMMONIA, PO-	Sulphuric	Benzoic	ACID.
Iron	TASH & SODA.	Phosphoric	Acetic	Barytes
Tin	Acids	Oxalic	Boracic	Strontites
Hydrogen	Sulphuric	Tartaric	Sulphurous	Lime
Antimony	Nitric	Fluoric	Carbonic	Potash
Phosphorus	Muriatic	Nitric	Prussic	Soda
Sulphur	Phosphoric	Muriatic	Sulphur	Magnesia
Arsenic	Fluoric	Succinic		Ammonia
Cobalt	Oxalic	Acetic	ARGIL.	Argil
Nickel	Tartaric	Arsenic	Acids	Metallic oxides
Copper	Arsenic	Boracic	Sulphuric	
Bismuth	Succinic	Carbonic	Nitric	ACIDS, PHOS-
Mercury	Citric	Sulphur	Muriatic	PHORIC, FLUO-
Silver	Benzoic		Fluoric	RIC, BORACIC,
Gold	Sulphurous	LIME.	Arsenic	OXALIC, TAR-
Platina	Acetic	Acids	Oxalic	TARIC, ARSE-
	Saccho-lactic	Oxalic	Tartaric	NIC, CITRIC,
NITROGEN.	Boracic	Sulphuric	Phosphoric	BENZOIC, SUC-
Oxygen	Nitrous	Tartaric	Acetic	CINIC, SACCHO-
Hydrogen	Carbonic	Succinic		LACTIC.
	Prussic	Phosphoric	SILEX.	Lime
HYDROGEN.	Oil	Saccho-lactic	Fluoric Acid	Barytes
Oxygen	Water	Nitric	Potash	Strontites
Sulphur	Sulphur	Muriatic		Magnesia
Carbon		Fluoric	ACIDS, NITRIC,	Potash
Phosphorus	BARYTES.	Arsenic	NITROUS AND	Soda
Nitrogen	Acids	Citric	MURIATIC.	Ammonia
	Sulphuric	Benzoic	Potash	Argil
CARBON.	Oxalic	Acetic	Soda	Metallic oxides
Oxygen	Succinic	Boracic	Barytes	
Iron	Fluoric	Sulphurous	Strontites	CARBONIC
Hydrogen	Phosphoric	Nitrous	Lime	ACID.
	Saccho-lactic	Carbonic	Ammonia	Barytes
	Nitric	Prussic	Magnesia	Strontites
SULPHUR.	Muriatic	Sulphur	Argil	Lime
Oxygen	Citric		Metallic oxides	Fixed Alkalis
Potash	Tartaric	MAGNESIA.		Magnesia
Soda	Arsenic	Acids	SULPHURIC	Ammonia
Iron	Benzoic	Oxalic	ACID.	Argil
Copper	Acetic	Phosphoric	Barytes	Metallic oxides
Tin	Boracic	Sulphuric	Strontites	
Lead	Sulphurous	Fluoric	Potash	ACETIC ACID.
Silver	Nitrous	Arsenic	Soda	Barytes
Bismuth			Lime	



Potash	Ammonia	Volatile Oils	VOLATILE OILS.	Volatile Oil
Soda	Lime	Ammonia	Ether	Fixed Alkali
Ammonia	Barytes	Fixed Alkalis	Alcohol	Volatile Alkali
Lime	Strontites	Sulphur	Fixed Oil	Sulphur
Magnesia	Magnesia	Muriates	Fixed Alkalis	
Argil	Argil		Sulphur	
Metallic oxides	Metallic oxides	ETHER.		
		Alcohol	FIXED OILS.	
PRUSSIC ACID.	ALCOHOL.	Volatile Oils	Lime	
Potash	Water	Water	Metallic oxides	
Soda	Ether		Ether	

The following is, I believe, the most copious table of the chemical equivalents or atomic weights of substances, which will be found in any elementary chemical work ; and I have endeavoured, by selecting them from the best authorities, to render the numbers as correct as possible. The numbers are arranged in two columns, one in reference to hydrogen as 1, the other to oxygen as 10. The constitution of any of the compounds which it includes, may be easily learnt by comparing its equivalent with those of its component parts ; the equivalent of potash, for instance, is 48, that of potassium is 40, and that of oxygen 8 : it is obvious, therefore, that potash must consist of one atom or one proportion of each ingredient. The composition of the more important salts has been already given more fully in tables,—of those of ammonia at page 22 ; of potash, p. 50 ; of soda, p. 61 ; of barytes, p. 76 ; of strontites, p. 81 ; of lime, p. 89 ; of magnesia, p. 96 ; of alumina, p. 104. A complete table of the composition of metallic oxides has also been given at page 128. The principal numbers in the following table will be found in Dr Wollaston's Scale of Chemical Equivalents, enlarged by Mr Reid, and adapted to the more convenient standard of hydrogen,—an instrument which will be found of the greatest utility in chemical researches.



TABLE OF CHEMICAL EQUIVALENTS.

	Atomic Weights.			Atomic Weights.	
	H. = 1.	O. = 10		H. = 1.	O. = 10.
Acid, acetic	50	62.5	oleic	288	360
cryst. 1 water	59	73.75	oxalic (dry)	36	45
arsenic	62	77.5	cryst. 4 water	72	90
benzoic,	120	150	perchloric	92	115
boracic	24	30	phosphorous	20	25
cryst. 2 water	42	52.5	phosphoric	28	35
bromic ?	115 ?	143.75 ?	prussic	27	33.75
carbonic	22	27.5	purpuric	44	55
chloric	76	95	pyro-citric	97	121.25
chloriodic	196	245	pyro-uric	251	313.75
chloro-carbonic,			saccho-lactic	104	130
(phosgene gas)	50	62.5	selenic	56	70
chloro-cyanic	62	77.5	siliceo-fluoric	26	32.5
chromic	52	65	succinic	50	62.5
citric	58	72.5	sulpho-chyazic or		
cryst. 2 water	76	95	sulpho-cyanic	59	73.75
cyanic ?	34	42.5	sulphovinic	108	135
ferro-prussic ?	117	146.25	sulphurous	32	40
ferro-cyanic ?	108 ?	135 ?	sulphuric (dry)	40	50
fluo-boric	34	42.5	liquid, sp. gr. 1.85,		
fluoric	10	12.5	1 water	49	61.25
fluoric, (on Ampere's			tartaric	66	82.5
view)	19	23.75	cryst. 1 water	75	93.75
formic	37	46.25	tungstic	150	187.5
gallic	62	77.5	uric	72	90
hydriodic	125	156.25	cryst. 2 water	90	112.5
hydrocyanic (prus-			Albumen ?	180	225
sic)	27	33.75	Alcohol	23	28.75
hydrobromic ?	76 ?	95 ?	Aluminum	10	12.5
hyponitrous	38	47.5	Alumina	18	22.5
hypophosphorous	32	40	hydrate	27	33.75
hyposulphurous	24	30	bihydrate	36	45
hyposulphuric	72	90	Ammonia	17	21.25
iodic	164	205	Antimony	44	55
malic	60	75	chloride	80	100
manganeseous ?	52	65	subchloride	124	155
manganesic ?	60	75	iodide	168	210
margaric	264	330	protoxide	52	65
molybdic	72	90	deutoxide	56	70
muriatic, dry (of the			peroxide	60	75
old theory)	28	35	sulphuret	60	75
muriatic, gaseous	37	46.25	Arsenic	38	47.5
nitrous	46	57.5	chloride	74	92.5
nitric (dry)	54	67.5	iodide	162	202.5
liquid sp. gr. 1.5,			oxide, white (arse-		
2 water,	72	90	nious acid)	54	67.5



Atomic Weights. H. = 1. O. = 10.			Atomic Weights. H. = 1. O. = 10.		
seleniuret	78	97.5	bisulphuret	38	47.5
sulphuret (realgar)	54	67.5	phosphuret	18	22.5
sesquisulphuret (orpiment)	62	77.5	Carbonic oxide	14	17.5
Azote or nitrogen	14	17.5	Carburetted hydrogen	8	10
Barium	70	87.5	Cerium	50	62.5
chloride	106	132.5	chloride	86	107.5
iodide	194	242.5	oxide	58	72.5
oxide (barytes)	78	97.5	peroxide	62	77.5
peroxide	86	107.5	sulphuret	66	82.5
phosphuret	82	102.5	Camphor	77	96.25
sulphuret	86	107.5	Cerulin	166	207.5
Barytes	78	97.5	Chlorine	36	45
hydrate 1 water	87	108.75	hydrate (10 water)	126	157.5
cryst. 20 water	258	322.5	oxide (euchlorine)	44	55
Bismuth	72	90	tritoxide?	60	75
chloride	108	135	peroxide	68	85
iodide	196	245	Chrome	28	35
oxide	80	100	chloride	64	80
phosphuret	84	105	oxide	36	45
sulphuret	88	110	deutoxide	44	55
Boron	8	10	sulphuret	44	55
bichloride	80	100	Cinchonine	315?	393.75?
Brome	75?	93.75?	Cobalt	26	32.5
Brucine	412	515	chloride	62	77.5
Cadmium	56	70	iodide	150	187.5
chloride	92	115	oxide	34	42.5
iodide	180	225	peroxide	38	47.5
oxide	64	80	phosphuret	38	47.5
phosphuret	68	85	sulphuret	42	52.5
sulphuret	72	90	Columbium	144	180
Calcium	20	25	oxide (columbic acid)?	152	190
chloride	56	70	sulphuret	160	200
iodide	144	180	Copper (32 Thomson)	64	80
oxide (lime)	28	35	chloride	100	125
phosphuret	32	40	perchloride	136	170
sulphuret	36	45	iodide	188	235
Calomel, or chloride of mercury	236	295	oxide	72	90
Carbon	6	7.5	peroxide	80	100
chloride	42	52.5	phosphuret	76	95
sesquichloride	61	76.25	sulphuret	80	100
perchloride	120	150	bisulphuret	96	120
subchloride	48	60	Corrosive sublimate (bichloride of mercury)	272	340
hydrochloride (chloric ether)	50	62.5	Cyanogen	26	32.5
hydriodide	138	172.5	iodide	150	187.5
hydruret (olefiant gas or bicarb. hydr.)	14	17.5	Ether, sulphuric	37	46.25
bihydruret (carburetted hydrogen)	8	10	muriatic	51	63.75
			chloric	50	62.5
			Euchlorine	44	55



Atomic Weights.			Atomic Weights.		
H. = 1. O. = 10.			H. = 1. O. = 10.		
Fibrin	204	255	sulphuret	44	55
Fluoron or Fluoricum	2	12.5	persulphuret	60	75
Fluorine (on Ampere's view)	18 ?	22.5 ?	Lead	104	130
Glucinum	18	22.5	chloride	140	175
chloride	54	67.5	iodide	228	285
Glucina	26	32.5	oxide (massicot)	112	140
Gold	200	250	deutoxide	116	145
chloride	256	295	peroxide	120	150
bichloride	272	340	sulphuret (galena)	120	150
iodide	324	405	bisulphuret	136	170
oxide	208	260	subsulphuret	224	280
peroxide	224	280	Lime (calcium 20)	28	35
sulphuret	248	310	chloride	64	80
Gum	90	112.5	subchloride	92	115.
Hydrogen	1	1.25	hydrate	37	46.25
arseniuretted	39	48.75	Lithium	10	12.5
carburetted, light	8	10	chloride	46	57.5
bicarburetted (olefiant gas)	14	17.5	iodide	134	167.5
quadrocarburetted	28	35	oxide (lithia)	18	22.5
bicarburet of	39	48.75	sulphuret	26	32.5
sesquicarburet of (naphthaline)	10	12.5	Lithia	18	22.5
deutoxide (oxygenated water)	17	21.25	Magnesium	12	15
seleniuretted	41	51.25	oxide (magnesia)	20	25
sulphuretted	17	21.25	sulphuret	28	35
bisulphuretted	33	41.25	Magnesia	20	25
telluretted	33	41.25	chloride	56	70
Hydruret of phosphorus	13	16.25	hydrate	29	36.25
bihydruret of phosphorus	14	17.5	Manganese	28	35
Indigo	150	162.5	chloride	64	80
Iodine	124	155	oxide	36	45
chloride (chloriodic acid)	196	245	deutoxide	40	50
hydrocarburet	138	172.5	tritoxide	44	55
Iridium	30	37.5	phosphuret	40	50
chloride	66	82.5	sulphuret	44	55
oxide	38	47.5	Mercury	200	250
peroxidé	46	57.5	chloride (calomel)	236	295
Iron	28	35	bichloride (corrosive sublimate)	272	340
chloride	64	80	bicyanide	252	315
perchloride	82	102.5	iodide	324	405
hydrated peroxide	49	61.25	periodide	448	560
iodide	152	190	protoxide	208	260
protoxide	36	45	peroxide	216	270
peroxide	40	50	sulphuret	216	270
			persulphuret (cinabar)	232	290
			Molybdenum	48	60
			oxide	56	70
			deutoxide (molybdous acid ?)	64	80



Atomic Weights. H. = 1. O. = 10.			Atomic Weights. H. = 1. O. = 10.		
peroxide (molybdic acid)	72	90	bichloride	168	210
bisulphuret	80	100	oxide	104	130
Morphine	322 ?	402.5 ?	peroxide	112	140
Murion (of the old theory)	12	15	sulphuret	112	140
Naphtha	42	52.5	bisulphuret	128	160
Naphthaline	10	12.5	Potassium	40	50
Nickel	26	32.5	bromide ?	115 ?	143.75 ?
chloride	62	77.5	chloride	76	95
iodide	150	187.5	iodide	164	205
oxide	34	42.5	oxide (potash)	48	60
peroxide	38	47.5	peroxide	64	80
phosphuret	38	47.5	phosphuret	52	65
sulphuret	42	52.5	subphosphuret	92	115
Nitrogen	14	17.5	sulphuret	56	70
chloride (4 chlorine ?)	158 ?	197.5 ?	bisulphuret	72	90
bicarburet (cyanogen)	26	32.5	tritrosulphuret	88	110
iodide (3 iodine ?)	386	482.5	quadrosulphuret	104	130
oxide (nitrous ox.)	22	27.5	persulphuret	120	150
deutoxide (nitric oxide)	30	37.5	Potash	48	60
Oil gas (tritohydrocarburet Th.)	21	26.25	hydrate, 1 water	57	71.25
Oil of turpentine	102 ?	127.5	Pyroxylic spirit	75 ?	93.75
Olefiant gas (2 carbon and 2 hydrogen)	14	17.5	Pyro-acetic spirit	43 ?	53.75
superolefiant gas ?	21	26.25	Quinine	360 ?	450
Olive oil ?	79	98.75	Rhodium	44	55
Oil of wine, or ethereal oil ?	136	170	chloride	80	100
Oil, whale ?	77	96.25	oxide	52	65
Oxygen	8	10	peroxide	60	75
Palladium	56	70	sulphuret	60	75
oxide	64	80	Selenium	40	50
sulphuret	72	90	bichloride	112	140
Phenecin ?	148	185	oxide	48	60
Phosphorus	12	15	perox. (selen. acid)	56	70
chloride	48	60	sesquisulphuret	64	80
bichloride	84	105	Selenureted hydrogen	41	51.25
carburet	18	22.5	Silicon or silicium	8	10
hydruret	13	16.25	oxide (silica)	16	20
bihydruret	14	17.5	Silica	16	20
iodide	136	170	hydrate	25	31.25
sulphuret	28	35	Silver	110	137.5
Phosphuret. hydrog.	13	16.25	chloride	146	182.5
Picrotoxine	360 ?	450 ?	iodide	234	292.5
Platina	96	120	oxide	118	147.5
chloride	132	165	suboxide	173	216.25
			phosphuret	122	152.5
			sulphuret	126	157.5
			Sodium	24	30
			chloride	60	75
			iodide	148	185
			oxide (soda)	32	40
			peroxide	36	45
			phosphuret	36	45



Atomic Weights.			Atomic Weights.		
H. = 1. O = 10.			H. = 1. O = 10.		
sulphuret	40	50	sesquisulphuret	82	102.5
Soda	32	40	bisulphuret (mosaic		
hydrate, 1 water	41	51.25	gold)	90	112.5
Starch ?	142	177.5	Titanium	32	40
Strontium	44	55	oxide	40	50
chloride	80	100	peroxide (titanic		
iodide	168	210	acid ?)	48	60
oxide (strontites)	52	65	sulphuret	48	60
phosphuret	56	70	Tungsten	126	157.5
sulphuret	60	75	oxide	142	177.5
Strontites	52	65	bisulphuret	158	197.5
hydrate, 1 water	61	76.25	Uranium	208	260
Strychnine	580	475	chloride	244	305
Sugar	75	93.75	oxide	216	270
Sulphur	16	20	peroxide	224	280
chloride	52	65	sulphuret	224	280
subchloride	68	85	Urée	30	37.5
iodide	140	175	Water	9	11.25
phosphuret	28	35	Wax	97	121.25
Sulphuretted hydrog.	17	21.25	Yttrium	34	42.5
bisulphuret. hyd.	33	41.25	chloride	70	87.5
Sulphuric ether	37	46.25	oxide (yttria)	42	52.5
Tannin	71 ?	88.75	Zinc	34	42.5
Tellurium	32	40	chloride	70	87.5
chloride	68	85	iodide	158	197.5
oxide	40	50	oxide	42	52.5
Tin	58	72.5	phosphuret	46	57.5
chloride	94	117.5	sulphuret	50	62.5
bichloride	130	162.5	Zirconium	40	50
oxide	66	82.5	chloride	76	95
deutoxide	74	92.5	oxide (zircon)	48	60
phosphuret	70	87.5	Zircon	48	60
sulphuret	74	92.5	hydrate	57	71.25

## SALTS.

Alumina	18	22.5	oxalate, 3 water	81	101.25
acetate, cryst. 1			phosphate	46	57.5
water	77	96.25	3 water	73	91.25
arsenate	80	100	sulphate	58	72.5
cryst. 6 water	134	167.5	7 water	121	151.25
fluat	28	45	subsulphate 9 wat.	175	218.75
muriate, cryst. 3			sulphate of potash		
water	82	102.5	and, (alum) dry	262	327.5
nitrate, (dinitrate,			cryst. 25 water		
Thomson) cryst.			(com. alum)	487	608.75
10 water	180	225	tartrate	84	105
subnitrate, (tris-			1 water	93	116.25
nitrate, Thom-			Ammonia	17	21.25
son) 6 water	162	202.5	acetate	67	83.75



Atomic Weights.			Atomic Weights.		
H. = 1. O. = 10.			H. = 1. O. = 10.		
cryst. 7 water	130	162.5	acetate	128	160
arseniate	79	98.75	cryst. 3 water	155	193.75
binarseniate cryst.			arseniate	140	175
2 water	159	198.75	arsenite ?	132	165
benzoate cryst. 1			borate	102	127.5
water	146	182.5	carbonate	100	125
borate	41	51.25	chlorate	154	192.5
cryst. 2 water	59	73.75	chromate	130	162.5
carbonate	39	48.75	citrate	136	170
sesquicarbonate			ferro-prussiate	195	243.75
1 water	59	73.75	fluante	88	110
bicarbonate	61	76.25	hydriodate	203	253.75
cryst. 1 water	70	87.5	binhyposulphite	126	157.5
chlorate	93	116.25	iodate	242	302.5
chromate	69	86.25	muriate cryst. 1		
bichromate	121	151.25	water	124	155
cryst. 2 water	139	173.75	nitrate	132	165
citrate	75	93.75	oxalate	114	142.5
fluoborate	51	63.75	cryst. 3 water	141	176.25
bifluoborate	85	106.25	binoxalate 3 w.	177	221.25
fluosilicate	69	86.25	phosphate	106	132.5
hydriodate	142	177.5	biphosphate 2 wa-		
iodate	181	226.25	ter	152	190
molybdate	89	111.25	phosphite	98	122.5
bimolybd. 1 wat.	170	212.5	succinate	128	160
muriate	54	67.5	sulphate	118	147.5
nitrate	71	88.75	sulphite	110	137.5
cryst. 1 water	80	100	tartrate	144	180
oxalate	53	66.25	bitartrate cryst.		
cryst. 2 water	71	88.75	2 water	228	285
binoxalate 8 wat.	161	201.25	Bismuth, protoxide	80	100
phosphate	45	56.25	acetate	130	162.5
cryst. 2 water	63	78.75	arseniate 2 water	160	200
biphosphate	73	91.25	carbonate	102	127.5
phosphite	37	46.25	chromate 2 water	150	187.5
sac lactate 1 water	130	162.5	citrate	138	172.5
succinate	67	83.75	iodate	244	305
cryst. 2 water	85	106.25	muriate	117	146.25
sulphate	57	71.25	nit. cryst. 3 water	161	201.25
cryst. 1 water	66	82.5	oxalate	116	145
sulphite	49	61.25	phosphate	108	135
tartrate	83	103.75	3 water	135	168.75
bitungstate	317	396.25	sulphate	120	150
2 water	335	418.75	subsulphate	280	350
Antimony, protoxide	52	65	tartrate 5 water	191	238.75
hydrosulphuret			Cadmium, protoxide	64	80
(kermes mineral)	69	86.25	acetate cryst. 2		
tartrate of potash,			water	132	165
and, 2 water (eme-			arseniate 1 water	155	168.75
tic tartar)	354	442.5	carbonate	86	107.5
Barytes	78	97.5	chromate 5 wat.	161	201.25



	Atomic Weights. H.=1. O.=10.			Atomic Weights. H.=1. O.=10.	
citrate 2 water	140	175	binitrate	188	235
muriate 1 water	110	137.5	cryst. 7. water	251	313.75
nitrate cryst. 4			subnitrate (1 acid		
water	154	192.5	and 4 base)	374	467.5
oxalate 3 water	127	1587.5	phosphate	108	135
phosphate 1 wat.	101	126.25	biphosphate	136	170
sulphate cryst. 4			2 water	154	192.5
water	140	175	bisulphate (blue		
tartrate 2 water	148	185	vitriol)	160	200
Cerium, protoxide	58	72.5	cryst. 10 water	250	312.5
carbonate	80	100	subsulphate (1		
muriate	95	118.75	acid and 2		
sulphate	98	122.5	base)	200	250
3 water	125	156.25	Glucine	26	32.5
Chrome, protoxide	36	45	muriate	63	78.75
muriate 9 water	154	192.5	sulphate	66	82.5
Cobalt, protoxide	34	42.5	bisulphate	106	132.5
acetate	84	105	5 water	151	188.75
arseniate	96	120	Iron, protoxide	36	45
4 water	132	165	acetate 3 water	113	141.25
carbonate	56	70	subarseniate cryst.		
1 water	65	81.25	3 water	161	201.25
chromate 2 water	104	130	carbonate	58	72.5
muriate 4 water	107	133.75	muriate 3 water	100	125
nitrate	88	110	nitrate c. 7 w.	153	191.25
cryst. 6 water	142	177.5	sesquinitrate		
oxalate	70	87.5	(peroxide)		
2 water	88	110	8 water	193	241.25
phosphate	62	77.5	oxalate	72	90
2 water	80	100	2 water	90	112.5
sulphate	74	92.5	phosphate	64	80
cryst. 7 water	137	171.25	cryst. 3 water	91	113.75
bisulphate	114	142.5	subphosphate (per-		
cryst. 3 water	141	176.25	oxide) 3 w.	175	218.75
tartrate	100	125	succinate	90	112.5
cryst. 2 water	118	147.5	sulphate	76	95
Copper, peroxide	80	100	cryst. 7 water		
acetate	130	162.5	(green vitriol)	159	173.75
cryst. 6 wat. (com-			sesquisulphate,		
mon verdigris)	184	230	(peroxide)	100	125
binacetate	180	225	sulphite	68	85
c. 3 w. (distilled			tartrate	102	127.5
verdigris)	207	258.75	cryst. 2 water	120	150
subacetate (1 acid			Lead, protoxide	112	140
2 base)	210	262.5	acetate	162	202.5
arseniate	142	177.5	cryst. 3 water	189	236.25
carbonate	102	127.5	subacetate	274	342.5
1 w. (malachite)	111	138.75	subtriacetate		
nitrate cryst. 7			(Goulard's		
water	197	246.25	extract)	586	482.5



Atomic Weights.			Atomic Weights.		
H.=1. O.=10.			H.=1. O.=10.		
arseniate	174	217.5	succinate	78	97.5
subarseniate	250	287.5	sulphate	68	85
benzoate	252	290	c. 2 w. (gypsum)	86	107.5
cryst. 1 water	241	301.25	sulphite	60	75
carbonate	134	167.5	tartrate	94	117.5
chlorate	188	235	4 water	130	162.5
chromate	164	205	tungstate	178	222.5
bichromate ?	216	270	Lithia or lithina	18	22.5
subchromate	276	345	carbonate	40	50
citrate	170	212.5	muriate	55	68.75
fluante	122	152.5	nitrate	72	90
formate cryst.			phosphate	46	57.5
1 water	158	197.5	sulphate 1 water	67	83.75
gallate	175	218.75	Magnesia	20	25
hyponitrite 1 w.	159	198.	acetate	70	87.5
malate	172	215	cryst. 5 water	115	143.75
molybdate	184	230	arseniate	82	102.5
nitrate	166	207.5	cryst. 8 water	154	192.5
subnitrate	278	347.5	biborate	68	85
oxalate	148	185	carbonate	42	52.5
phosphate	140	175	cryst. 3 water	69	86.25
subphosphate	252	315	chloride	56	70
phosphite	132	165	chromate	72	90
succinate	162	202.5	muriate	57	71.25
sulphate	152	190	cryst. 5 water	102	127.5
sulphite	144	180	nitrate	74	92.5
tartrate	178	222.5	cryst. 6 water	128	160
tungstate	262	327.5	oxalate	56	70
Lime	28	35	2 water	74	92.5
acetate	78	97.5	binoxalate cryst.		
6 water	132	165	7 water	155	193.75
arseniate	90	112.5	phosphate	48	60
benzoate	148	185	cryst. 7 water	111	138.75
carbonate	50	62.5	phosphate of am-		
chlorate	104	130	monia and,	93	116.25
chloride	64	80	crys. 4 water	129	161.25
subchloride	92	115	sulphate	60	75
6 water	146	182.5	sulphate of soda		
chromate	80	100	and, c. 7. w.	123	153.75
citrate	86	107.5	tartrate	86	107.5
fluante	38	47.5	2 water	104	130
hydriodate	153	191.25	bitartrate c. 1 w.	161	201.25
binhyposulphite			Manganese, prot-		
6 water	130	162.5	oxide, green	36	45
iodate	192	240	acetate	86	107.5
muriate c. 6 w.	119	148.75	cryst. 4 water	122	152.5
nitrate	82	102.5	arseniate c. 10 w.	188	235
3 water	109	136.25	benzoate	156	195
oxalate	64	80	carbonate	58	72.5
2 water	82	102.5	cryst. 2 water	76	95
phosphate	56	70	muriate c. 4 w.	109	136.25



Atomic Weights. H. = 1. O. = 10.			Atomic Weights. H. = 1. O. = 10.		
nitrate	90	112.5	tartrate	100	125
cryst. 7 water	153	191.25	Platina, muriate of		
oxalate	72	90	ammonia and,	222	277.5
cryst. 3 water	99	123.75	sulphate	152	190
phosphate	64	80	Potash	48	60
sulphate	76	95	acetate	98	122.5
cryst. 5 water	121	151.25	binacetate, cryst.		
tartrate	102	127.5	6 water	202	252.5
cryst. 2 water	120	150	arseniate	110	137.5
Mercury, protoxide	208	260	binarseniate	172	215
acetate	258	322.5	cryst. 1 water	181	226.25
4 water	294	367.5	arsenite	102	127.5
arseniate	270	337.5	benzoate	168	210
sesquicarbonate	241	301.25	cryst. 3 water	195	243.75
chlorate	284	355	carbonate	70	87.5
chromate	260	325	cryst. 2 water	88	110
nitrate	262	327.5	bicarbonate	92	115
cryst. 2 water	280	350	cryst. 1 water	101	126.25
pernitrate (per-			chlorate	124	155
oxide)	270	337.5	chromate	100	125
subnitrate (per-			bichromate	152	190
oxide)	486	607.5	citrate	106	132.5
oxalate	244	305	hydriodate	173	216.25
cryst. 1 water	253	316.25	hydrobromate	124 ?	155 ?
phosphate	236	295	iodate	212	265
sulphate	248	310	molybdate	120	150
cryst. 2 water	266	332.5	nitrate (nitre)	102	127.2
persulphate (per-			oxalate	84	105
oxide)	256	320	cryst. 1 water	93	116.25
bipersulphate			binoxalate	120	150
(peroxide)	296	370	cryst. 2 water	138	172.5
cryst. 1 water	305	381.25	quadroxalate	192	240
tartrate	274	342.5	cryst. 7 water	255	318.75
Nickel, protoxide	34	42.5	perchlorate	140	175
acetate	84	105	phosphate	76	95
cryst. 5 water	129	161.25	cryst. 1 water	85	106.25
arseniate	96	120	biphosphate	104	130
6 water	150	187.5	succinate	98	122.5
binarseniate, 10 w.	248	310	sulphate	88	110
carbonate	56	70	bisulphate	128	160
3 water	83	103.75	cryst. 2 water	146	182.5
chromate, 4 water	122	152.5	sulphite	80	100
muriate, 5 water	116	145	tartrate	114	142.5
nitrate	88	110	cryst. 2 water	132	165
cryst. 5 water	133	166.25	bitartrate c. 1 w.		
oxalate	70	87.5	(cr. of tar.)	189	236.25
4 water	106	132.5	tungstate	198	247.5
phosphate	62	77.5	Quinine, sulphate	400 ?	500 ?
3 water	89	111.25	Silver, protoxide	118	147.5
sulphate	74	92.5	acetate	168	210
cryst. 7 water	137	171.25	arseniate	180	225



	Atomic Weights. H.=1. O.=10.			Atomic Weights. H.=1. O.=10.	
subarsenate	239	298.75	tungstate	182	227.5
arsenite	172	215	6 water	236	295
carbonate	140	175	urate 1 water	113	141.25
chlorate	194	242.5	Strontites	52	65
chromate	170	212.5	acetate	102	127.5
iodate	282	352.5	cryst. 1 water	111	138.75
molybdate	190	237.5	arsenate	114	142.5
mur. (old theory)	146	182.5	cryst. 8 water	186	232.5
nitrate	172	215	carbonate	74	92.5
oxalate	154	192.5	chlorate	128	160
phosphate	146	182.5	chromate	104	130
sulphate	158	197.5	citrate	110	137.5
tartrate	184	230	muriate cryst. 5 w.	134	167.5
Soda	32	40	nitrate	106	132.5
acetate	82	102.5	oxalate	88	110
cryst. 6 water	136	170	cryst. 2 water	106	132.5
arsenate	94	117.5	binoxalate	124	155
cryst. 8 water	166	207.5	phosphate	80	100
binarsenate c. 5			cryst. 1 water	89	111.25
water	201	251.25	biphos. c. 2 w.	126	157.5
arsenite	86	107.5	sulphate	92	115
benzoate	152	190	tartrate	118	147.5
biborate (borax) 8			cryst. 5 water	145	181.25
water	152	190	Tin, oxide	66	82.5
carbonate (subcar.)	54	67.5	muriate	103	128.75
cryst. 10 water	144	180	bimuriate (peroxide		
sesquicarbonate			74) 3 water	175	218.75
cryst. 2 water	83	103.75	Uranium, peroxide	224	280
bicarbonate	76	95	carbonate 1 water	255	318.75
cryst. 1 water	85	106.25	sesquinitrate	305	381.25
chlorate	108	135	sesquisulphate, 4		
chromate	84	105	water	320	400
cryst. 12 water	192	240	Uree, subnitrate	114	142.5
citrate	90	112.5	Zinc, oxide	42	52.5
hydriodate	157	196.25	acetate	92	115
iodate	196	245	cryst. 7 water	155	195.75
molybdate	104	130	arsenate	104	130
nitrate	86	107.5	8 water	176	220
oxalate	68	85	carbonate	64	80
binoxalate	104	130	1 water	73	91.25
cryst. 3 water	131	163.75	chlorate	118	147.5
phosphate	60	75	chromate	94	117.5
cryst. 12 water	168	210	muriate	79	98.75
sacactate 5 water	181	226.25	nitrate	96	120
succinate	82	102.5	cryst. 6 water	150	187.5
6 water	136	170	oxalate	78	97.5
sulphate	72	90	2 water	96	120
cryst. 10 water	162	202.5	phosphate	70	87.5
sulphite	64	80	biphosphate c. 4 w.	134	167.5
tartrate	98	122.5	succinate	92	115
2 water	116	145	sulphate	82	102.5
tartrate of potash			cryst. 7 water	145	181.25
and (Rochelle			sulphite	74	92.5
salt)	212	265	tartrate	108	135



TABLE BY DR THOMSON OF THE SPECIFIC GRAVITIES OF  
GASES AND VAPOURS.

	Sp. Gr. at 60°.	Weight of 100 cubic inches in grains.
Air .....	1	30.5
Hydrogen... ..	0.0694	2.1180
Carbon vapour .....	0.4166	12.6083
Carburetted hydrogen .....	0.5555	16.9444
Ammonia .....	0.59027	18.0035
Watery vapour .....	0.625	19.0620
Phosphorus vapour .....	0.0833	25.4166
Phosphuretted hydrogen .....	0.9027	27.5376
Prussic acid vapour .....	0.9375	28.5720
Bihydruret of phosphorus .....	0.9722	29.6527
Carbonic oxide .....	0.9722	29.6527
Nitrogen .....	0.9722	29.6527
Olefiant gas .....	0.9722	29.6527
Nitric oxide .....	1.04166	31.7708
Oxygen .....	1.1111	33.8888
Sulphur vapour .....	1.1111	33.8888
Sulphuretted hydrogen .....	1.1805	36.0069
Muriatic acid .....	1.28472	39.1839
Oil gas .....	1.4583	44.47917
Carbonic acid .....	1.5277	46.5972
Nitrous oxide .....	1.5277	46.5972
Alcohol vapour .....	1.597	48.6147
Cyanogen .....	1.8055	55.0694
Sulphurous acid .....	2.2222	67.7777
Tellurium vapour .....	2.2222	67.7777
Telluretted hydrogen .....	2.2916	69.89583
Fluoboric acid .....	2.3611	72.0135
Euchlorine .....	2.4444	74.5555
Chlorine .....	2.5	76.25
Sulphuric ether vapour .....	2.5694	78.3675
Arsenic vapour .....	2.6388	80.4861
Bisulphuret of carbon vapour .....	2.6388	80.4861
Selenium vapour .....	2.7777	84.6980
Sulphuric acid vapour .....	2.7777	84.6980
Seleniuretted hydrogen .....	2.8522	86.9927
Naphtha vapour .....	2.9166	88.9583
Chloro-carbonic acid .....	3.4722	105.9020
Siliceo-fluoric acid .....	3.6111	110.1385
Nitric acid .....	3.75	114.375
Hydriodic acid .....	4.34027	132.3785
Oil of turpentine vapour .....	5.0130	152.896
Iodine vapour .....	8.6111	262.6308



TABLE of the Linear Expansions of Different Solids by being heated from 32° to 212°, (vol. i. p. 112), expressed in vulgar fractions, from the experiments of Lavoisier and Laplace, Smeaton, and Roy.

Substances.	Dilata- tions.	Substances.	Dilata- tions.
Antimony, .....	$\frac{1}{524}$	Iron wire, .....	$\frac{1}{812}$
Bismuth, .....	$\frac{1}{715}$	Lead, .....	$\frac{1}{351}$
Brass, .....	$\frac{1}{334}$	Palladium, .....	$\frac{1}{1006}$
— .....	$\frac{1}{317}$	Pewter, .....	$\frac{1}{438}$
Copper, .....	$\frac{1}{382}$	Platina, .....	$\frac{1}{1167}$
Glass tube, crown, .....	$\frac{1}{1118}$	Silver, .....	$\frac{1}{324}$
— English flint, .....	$\frac{1}{1248}$	Speculum metal, .....	$\frac{1}{817}$
Gold pure, .....	$\frac{1}{882}$	Steel, soft, .....	$\frac{1}{526}$
— standard, .....	$\frac{1}{643}$	— tempered, .....	$\frac{1}{807}$
Iron, ... ..	$\frac{1}{793}$	Tin, Cornish, .....	$\frac{1}{462}$
— forged, .....	$\frac{1}{812}$	— grain, .....	$\frac{1}{403}$
— cast, .....	$\frac{1}{901}$	Zinc, .....	$\frac{1}{346}$

TABLE of the Expansions of several Liquids, by being heated from 32° to 212°, (vol. i. p. 115); the numbers, excepting the two last, are by Mr Dalton.

Water, .....	$\frac{1}{22}$	Ether, .....	$\frac{1}{14}$
— saturated with salt, .....	$\frac{1}{20}$	Oil of turpentine, .....	$\frac{1}{14}$
Sulphuric acid, .....	$\frac{1}{17}$	Fixed oils, .....	$\frac{1}{12}$
Muriatic acid, .....	$\frac{1}{17}$	Mercury, .....	$\frac{1}{50}$
Nitric acid, .....	$\frac{1}{9}$	— Lavoisier, .....	$\frac{1}{53.22}$
Alcohol, .....	$\frac{1}{9}$	— Dulong and Petit, ...	$\frac{1}{53.3}$

TABLE of the Expansions of Water in being heated from 32° to 212°, (vol. i. p. 116.) calculated by Dr Young, from the experiments of Gilpin.

Temp.	Expansion.	Temp.	Expansion.
30°	.00018	74°	.00251
32	.00011	79	.00326
34	.00005	90	.00513
39	.00000	100	.00720
44	.00005	102	.00763
48	.00018	122	.01264
49	.00022	142	.01859
54	.00048	162	.02512
59	.00084	182	.03219
64	.00130	202	.03961
69	.00186	212	.04322



TABLE by Deluc, of the Thermometric Indications of several Fluids, (vol. i. p. 116.) The liquids were placed in thermometers, each of which was then graduated, the space between the freezing and boiling points of water being divided into  $80^{\circ}$ : these thermometers were placed in the same vessel full of water, which was gradually heated.

Mer- cury.	Olive oil.	Essential oil of Chamomile	Essential oil of Thyme.	Alcohol.	Water saturated with salt.	Water.
$80^{\circ}$	$80^{\circ}$	$80^{\circ}$	$80^{\circ}$	$80^{\circ}$	$80^{\circ}$	$80^{\circ}$
75	74.6	74.7	74.3	73.8	74.1	71.0
70	69.4	69.5	68.8	67.8	68.4	62.0
65	64.4	64.3	63.5	61.9	62.6	53.5
60	59.3	59.1	58.3	56.2	57.1	45.8
55	54.2	53.9	53.3	50.7	51.7	38.5
50	49.2	48.8	48.3	45.3	46.6	32.0
45	44.0	43.6	43.4	40.2	41.2	26.1
40	39.2	38.6	38.4	35.1	36.3	20.5
35	34.2	33.6	33.5	30.3	31.3	15.9
30	29.3	28.7	28.6	25.6	26.5	11.2
25	24.3	23.8	23.8	21.0	21.9	7.3
20	19.3	18.9	19.0	16.5	17.3	4.1
15	14.4	14.1	14.2	12.2	12.8	1.6
10	9.5	9.3	9.4	7.9	8.4	0.2
5	4.7	4.6	4.7	3.9	4.2	0.4
0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE OF THE EFFECTS OF HEAT.

	Wedg. Fahren.			Wedg. Fahren.	
Platina, tungsten, molybdenum, &c. melt at above .....	170°	23177°	Silver melts, .....	28°	4717
Greatest heat of an air furnace, which neither melted nor softened Nankeen porcelain, .....	160	21877	Copper melts, .....	27°	4587
Chinese porcelain softened, .....	156	21357	Brass melts, .....	21	3807
Cast iron melted, .....	150	20577	Red-heat visible in day light, .....	0	1077
Greatest heat of a smith's forge, .....	125	17327	Red-heat in twilight, .....		884
Greatest heat of a glass furnace, .....	114	15897	Heat of a common fire, .....		800
Welding heat of iron, ...	95	13427	Iron bright red in the dark, ...		752
Gold melts, .....	32	5237	Zinc melts, .....		700
			Quicksilver boils, .....		656
			Linseed oil boils, .....		600
			Lead melts, .....		594
			Sulphuric acid boils, .....		590
			Sulphur boils, .....		570
			Phosphorus boils, .....		554
			Arsenic sublimes, .....		540
			Bismuth melts, .....		476



	Fahren.		Fahren
Tin melts, .....	442°	Blood freezes, .....	25
Oil of turpentine boils, .....	316	Strong wines freeze at about ...	20
Camphor melts, .....	303	Brandy freezes, .....	—7
Nitric acid boils, .....	248	Melting point of quicksilver, ..	—39
Saturated solution of salt boils, ..	225	Liquid ammonia crystallizes, ..	—42
Sulphur melts, .....	226	Nitric acid, spec. gr. 1.42, and	
Water boils (the barometer being		sulphuric acid, sp. gr. 1.64,	
at 30 inches,) .....	212	freeze, .....	—45
Alcohol boils, .....	176	Sulphuric ether congeals, .....	—47
Potassium melts, .....	150	Natural temperature observed at	
Wax melts, .....	149	Hudson's Bay, .....	—50
Ammonia boils, .....	140	Greatest cold of Melville Island, —	59
Phosphorus melts, .....	100	Ammoniacal gas condenses into a	
Ether boils, .....	96	liquid, .....	—54
Heat of the human blood, .....	98	Cold from diluted sulphuric acid	
Medium temperature of the globe, ..	50	and snow, the materials being	
Strong acetic acid, .....	50	at —57, .....	—78
Ice melts, .....	32	Greatest cold yet measured, ...	—91

Boiling Points of Water in different vessels, according to Munche  
and Gmelin, (vol. i. p. 140.)

Substance of the vessels.	Thermometer touching the bottom.	Thermometer $\frac{1}{2}$ an inch below the surface of the water.
Silver, .....	211.775°	211.55°
Platina, .....	211.775	210.875
Porcelain, .....	212.1	211.900
Marble, .....	212.1	211.66
Lead, .....	212.45	211.775
Tin, .....	212.7	211.775
White glass, .....	212.7	212.00
Copper, .....	212.9	212.225
Tinned iron, .....	213.24	211.66
Delft ware, .....	213.8	212.7
Green glass, .....	213.8	213.35



TABLE, by Mr DALTON, of the Elastic Force of Aqueous Vapour at each degree of Fahrenheit between zero and 300°, expressed in inches and parts of inches of Mercury, (referred to, vol. i. p. 139. and 154.)

Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.
0°	0.064	61°	0.542	121°	3.42	181°	15.50	241	50.50
1	0.066	62	0.560	122	3.50	182	15.86	242	51.34
2	0.068	63	0.578	123	3.59	183	16.23	243	52.18
3	0.071	64	0.597	124	3.69	184	16.61	244	53.03
4	0.074	65	0.616	125	3.79	185	17.00	245	53.88
5	0.076	66	0.635	126	3.89	186	17.40	246	54.68
6	0.079	67	0.655	127	4.00	187	17.80	247	55.54
7	0.082	68	0.676	128	4.11	188	18.20	248	56.42
8	0.085	69	0.698	129	4.22	189	18.60	249	57.31
9	0.087	70	0.721	130	4.34	190	19.00	250	58.21
10	0.090	71	0.745	131	4.47	191	19.42	251	59.12
11	0.093	72	0.770	132	4.60	192	19.86	252	60.05
12	0.096	73	0.796	133	4.73	193	20.32	253	61.00
13	0.100	74	0.823	134	4.86	194	20.77	254	61.92
14	0.104	75	0.851	135	5.00	195	21.22	255	62.85
15	0.108	76	0.880	136	5.14	196	21.68	256	63.76
16	0.112	77	0.910	137	5.29	197	22.13	257	64.82
17	0.116	78	0.940	138	5.44	198	22.69	258	65.78
18	0.120	79	0.971	139	5.59	199	23.16	259	66.75
19	0.124	80	1.00	140	5.74	200	23.64	260	67.73
20	0.129	81	1.04	141	5.90	201	24.12	261	68.72
21	0.134	82	1.07	142	6.05	202	24.61	262	69.72
22	0.139	83	1.10	143	6.21	203	25.10	263	70.73
23	0.144	84	1.14	144	6.37	204	25.61	264	71.74
24	0.150	85	1.17	145	6.53	205	26.13	265	72.76
25	0.156	86	1.21	146	6.70	206	26.66	266	73.77
26	0.162	87	1.24	147	6.87	207	27.20	267	74.79
27	0.168	88	1.28	148	7.05	208	27.74	268	75.80
28	0.174	89	1.32	149	7.23	209	28.29	269	76.82
29	0.180	90	1.36	150	7.42	210	28.84	270	77.85
30	0.186	91	1.40	151	7.61	211	29.41	271	78.89
31	0.193	92	1.44	152	7.81	212°	30.00	272	79.94
32°	0.200	93	1.48	153	8.01	213	30.60	273	80.98
33	0.207	94	1.53	154	8.20	214	31.21	274	82.01
34	0.214	95	1.58	155	8.40	215	31.83	275	83.13
35	0.221	96	1.63	156	8.60	216	32.46	276	84.35
36	0.229	97	1.68	157	8.81	217	33.09	277	85.47
37	0.237	98	1.74	158	9.02	218	33.72	278	86.50
38	0.245	99	1.80	159	9.24	219	34.35	279	87.63
39	0.254	100	1.86	160	9.46	220	34.99	280	88.75
40	0.263	101	1.92	161	9.68	221	35.63	281	89.87
41	0.273	102	1.98	162	9.91	222	36.25	282	90.99
42	0.283	103	2.04	163	10.15	223	36.88	283	92.11
43	0.294	104	2.11	164	10.41	224	37.53	284	93.25
44	0.305	105	2.18	165	10.68	225	38.20	285	94.35
45	0.316	106	2.25	166	10.96	226	38.89	286	95.48
46	0.328	107	2.32	167	11.25	227	39.59	287	96.64
47	0.339	108	2.39	168	11.54	228	40.30	288	97.80
48	0.351	109	2.46	169	11.83	229	41.02	289	98.96
49	0.363	110	2.53	170	12.13	230	41.75	290	100.12
50	0.375	111	2.60	171	12.43	231	42.49	291	101.28
51	0.388	112	2.68	172	12.73	232	43.24	292	102.45
52	0.401	113	2.76	173	13.02	233	44.00	293	103.63
53	0.415	114	2.84	174	13.32	234	44.78	294	104.80
54	0.429	115	2.92	175	13.62	235	45.58	295	105.97
55	0.443	116	3.00	176	13.92	236	46.39	296	107.14
56	0.458	117	3.08	177	14.22	237	47.20	297	108.31
57	0.474	118	3.16	178	14.52	238	48.02	298	109.48
58	0.490	119	3.25	179	14.83	239	48.84	299	110.64
59	0.507	120	3.33	180	15.15	240	49.67	300	111.81
60	0.524								



TABLE of the Elastic Force of Aqueous Vapour at different Temperatures above 32°, by Dr URE.

Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.
32	0.200	110°	2.456	180°	15.16	250°	61.90
40	0.250	115	2.820	185	16.90	255	67.25
50	0.360	120	3.300	190	19.00	260	72.30
55	0.416	125	3.830	195	21.10	265	78.04
60	0.516	130	4.366	200	23.60	270	86.30
65	0.630	135	5.070	205	25.90	275	93.48
70	0.726	140	5.770	210	28.88	280	101.90
75	0.860	145	6.600	212°	30.00	285	112.20
80	1.010	150	7.550	220	35.54	290	120.15
85	1.170	155	8.500	225	39.11	295	130.40
90	1.360	160	9.600	230	43.10	300	139.70
95	1.640	165	10.800	235	47.22	305	150.56
100	1.860	170	12.050	240	51.70	310	161.30
105	2.100	175	13.550	245	56.34	312	167.00

TABLE, by Dr URE, of the Elastic Force of the Vapours of Alcohol, Ether, Oil of Turpentine and Petroleum or Naphtha, at different Temperatures, expressed in Inches of Mercury.

Ether.		Alcohol, sp. gr. 0.813.				Oil of turpentine.		Petroleum.	
Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.
34°	6.20	32°	0.40	155°	20.30	304°	30.00	316	30.00
44	8.10	40	0.56	160	22.60	307.6	32.60	320	31.70
54	10.30	45	0.70	165	25.40	310	33.50	325	34.00
64	13.00	50	0.86	170	28.30	315	35.20	330	36.40
74	16.10	55	1.00	173	30.00	320	37.06	335	38.90
84	20.00	60	1.23	180	34.73	322	37.80	340	41.60
94	24.70	65	1.49	185.3	39.90	326	40.20	345	44.10
104	30.00	70	1.76	190	43.20	330	42.10	350	46.86
110	32.54	75	2.10	196.3	50.10	336	45.00	355	50.20
115	35.90	80	2.45	200	53.00	340	47.30	360	53.30
120	39.47	85	2.93	206	60.10	343	49.40	365	56.90
125	43.24	90	3.40	210	65.00	347	51.70	370	60.70
130	47.14	95	3.90	216	72.20	350	53.80	372	61.90
135	51.90	100	4.50	220	78.50	354	56.60	375	64.00
140	56.90	105	5.20	225	87.50	357	58.70		
145	62.10	110	6.00	230	94.10	360	68.80		
150	67.60	115	7.10	236	103.60	362	62.40		
155	73.60	120	8.10	240	111.24				
160	80.30	125	9.25	244	118.20				
170	92.80	130	10.60	248	126.10				
180	108.30	135	12.15	250	132.30				
190	124.80	140	13.90	254.3	143.70				
200	142.80	145	15.95	260	155.20				
210	166.00	150	18.00	264	166.10				



TABLE by Crawford and Irving of the Capacities of various Bodies for Caloric, (vol. i. p. 216.)

*Liquids.*

Arterial blood, .....	1.0300 C.	Alcohol, ... ..	.6021 C.
Water, .....	1.0000 —	Spermaceti oil, .....	.5000 —
Milk, .....	.9999 —	Sulphuric acid, .....	.4290 —
Alcohol, .....	.9300 I.	Oil of turpentine, .....	.4000 —
Venous blood, .....	.8928 C.	Sulphuric acid, .....	.3330 I.

*Solids.*

Ice, .....	.8000 I.	Iron, .....	.1430 I.
Flesh, .....	.7400 C.	Oxide of antimony, .....	.1666 C.
Rice, .....	.5060 —	Oxide of zinc, .....	.1369 —
Barley, .....	.4210 —	Iron, .....	.1269 —
Pit-coal, .....	.2777 —	Brass, .....	.1123 —
Charcoal, .....	.2631 —	Copper, .....	.1111 —
Chalk, .....	.2564 —	White oxide of tin, .....	.0990 —
White oxide of antimony		Zinc, .....	.0943 —
washed, .....	.2272 —	Tin, .....	.0704 —
Oxide of copper, .....	.2272 —	Yellow oxide of lead, .....	.0680 —
Quicklime, .....	.2229 —	Antimony, .....	.0645 —
Oxide of iron, .....	.1666 —	Lead, .....	.0352 —
Glass, .....	.2000 I.		

TABLE OF FREEZING MIXTURES.

	Temperature reduced.
Muriate of ammonia 5 parts, nitre 5, water 16, .....	from 50° to 10°
Muriate of ammonia 5 parts, nitrate of potash 5, sulphate } of soda 8, water 16,	..... 50 to 4
Nitrate of ammonia 1, water 1, ....	50 to 4
Sulphate of soda 8, muriatic acid 5, .....	50 to 0
Sulphate of soda 5, sulphuric acid diluted with an equal } weight of water 4 parts,	..... 50 to 3
Sulphate of soda 6, muriate of ammonia 4, nitre 2, di- } luted nitric acid 4,	..... 50 to 10
Phosphate of soda 9, diluted nitric acid 4, ..	50 to —12
Phosphate of soda 9, nitrate of ammonia 6, diluted } nitric acid 4 parts,	..... 50 to —21
Muriate of soda 1, snow 2 parts, .....	32 to —5
Nitric acid diluted 4, snow 7 parts, .....	32 to —30
Muriate of soda 2, muriate of ammonia 1, snow 5, .....	32 to —12
Carbonate of potash, snow, .....	32 to —17
Muriate of soda 10, nitrate of potash 5, snow 24, .....	32 to —18
Sulphuric acid diluted with one-half its weight of } water 2 parts, snow 3 parts,	... 32 to —23
Concentrated muriatic acid 5, snow 8, .....	32 to —27
Diluted nitric acid 4, snow 7, .....	32 to —30
Muriate of lime 5, snow 4, .....	32 to —40
————— 5, ——— 2, .....	32 to —50
————— 5, ——— 3, .....	32 to —53
Potash 4, snow 3, .....	32 to —51
Muriate of lime 2, snow 1, .....	0 to —66
————— 3, ——— 1, .....	—40 to —75
Sulphuric acid with half its weight water 10, snow 8, .....	—68 to — <del>124</del> 91



TABLE of the Solubility of Salts in water, (vol. i. p. 515.) exhibiting the quantities of each salt dissolved by 100 parts of water at 60° and at 212°.

	Temperature			Temperature	
	at 60°	at 212°		at 60°	at 212°
Nitrate of potash	14.3	100	Phosphate of ammonia	25	25
soda	33	100	magnesia	8	
ammonia	50	200	Muriate of potash (dry)	33	59
barytes	8	25	soda	35	41
strontites	100	200	ammonia	33	100
lime	400		barytes	34	59
magnesia	100	200	strontites	150	unlimited.
Sulphate of potash	10	26	lime	200	
soda	35	120	magnesia	very soluble.	
ammonia	50	100	mercury (cor. sub.)	5	50
lime	0.2	0.22	Chlorate, of potash	6	40
magnesia	100	644	Borax	8.4	16.8
copper	25	50	Bitartrate of potash	1.6	3.3
iron	50	100	Tartrate of potash	25	
zinc	33		Tartrate of potash and		
Alum	5	133	soda	20	
Carbonate of potash	25	80	Tartrate of potash and		
soda	50	100	antimony	6.6	33
ammonia	30	100	Acetate of potash	100	
Phosphate of potash	very soluble.		lead	25	25
soda	25	60			

TABLE of the Composition of Mineral Waters, stated in conformity to the more probable views of Dr Murray, (vol. ii. p. 415.)

CARBONATED WATERS.			
SELTZER. Bergman.		Carbonate of Lime - 34.8	
<i>Altered to Dr Murray's View.</i>		Sulphate of Magnesia - 44.5	
In one Gallon.		Sulphate of Lime - 54.5	
Carbonic Acid	- 138 cub in.	Sulphate of Soda - 14.9	
		Muriate of Lime - 11.6	
		Oxide of Iron - 4.5	
		Or if Carbonate of Soda be supposed to exist in the water, rather than Sulphate of Soda, the following will be the salts:—	
Carbonate of Soda	- 109.34 grs.	Carbonic Acid Gas 208 cub. in.	
Muriate of Soda (Chloride of Sodium)	- 54.03	Carbonate of Soda - 11.5	
Lime (Chloride of Calcium)	- 26.83	Magnesia 80	
Magnesia	45.72	Lime - 24.45	
PYRMONT. Bergman.		Sulphate of Magnesia 44.5	
<i>Altered to Dr Murray's View.</i>		Lime - 68.6	
In one Gallon.		Muriate of Lime - 1.6	
Carbonic Acid Gas	208 cub. in.	Oxide of Iron - 14.5	
Carbonate of Magnesia	- 80 grs.		



SPA. Bergman.  
*Altered to Dr Murray's View.*  
 In one Gallon.

Carbonic Acid Gas	-	104	cub. in.
Carbonate of Soda	-	12.93	
———— Magnesia	-	35.3	
———— Lime	-	10.56	
Muriate of Lime	-	1.28	
Oxide of Iron	-	4.5	

CARLSBAD. Bergman.  
*Altered to Dr Murray's View.*  
 In one Gallon.

Carbonic Acid	32 to 50	cub. in.
Carbonate of Soda	51.96	
Sulphate of Soda	-	70
Muriate of Soda	-	20.2
———— Lime	-	13.44
Oxide of Iron	-	0.125
Silica	-	2.5

CARLSBAD. Berzelius. (Temperature 165.)  
 In a Wine Gallon.

Carbonic Acid Gas	40	cub. in.
In 10,000 parts by weight.		
Carbonate of Soda	12.5200	
———— Lime	-	3.1219
———— Magnesia	-	1.8221
———— Strontites	-	0.0097
Sulphate of Soda	-	25.8714
Chloride of Sodium	-	10.4893
Fluate of Lime	-	0.0331
Phosphate of Lime	-	0.0019
———— Alumina	-	0.0034
Carbonate of Iron	-	0.0424
———— Manganese	-	a trace
Silica	-	0.7504
		54.6656

*Altered to Dr Murray's View.*  
 In a Wine Gallon.

Carbonic Acid Gas	40	cub. in.
In 10,000 parts by weight.		
Carbonate of Soda	-	18.388
Sulphate of Soda	-	25.8714
Muriate of Soda	-	3.82507
———— Lime	-	3.54723
———— Magnesia	-	2.08224
———— Strontites	-	0.010486
———— Alumina	-	0.0034
———— Iron	-	0.046745
———— Manganese	-	a trace
Fluate of Soda	-	0.03658

Phosphate of Soda	-	0.006441
Silica	-	0.7504

SULPHUREOUS WATERS.

HARROGATE WATER. Old Well.  
*On Dr Murray's View.*  
 In one Gallon.

Nitrogen	-	8	cub. in.
Carbonic Acid	-	4.25	
Sulphuretted Hydrogen	14.		
Carburetted Hydrogen	4.15		

Muriate of Soda	-	752	grs.
———— Lime	-	65.75	
———— Magnesia	-	29.2	
Bicarbonate of Soda	-	12.8	

HARROGATE WATER. New Well.  
 In a Gallon.

Nitrogen Gas	-	6.5	cub. in.
Carbonic Acid Gas	-	5.25	
Sulphuretted Hydrogen	-	6.4	
Carburetted Hydrogen	-	4.65	
Muriate of Soda	-	735	grs.
———— Lime	-	71.5	
———— Magnesia	-	43	
Bicarbonate of Soda	-	14.75	

CHELTENHAM. Sulphur Spring.

The analysis of this water by Brande and Parkes, altered to agree with Dr Murray's views, gives for its composition,

In a Wine Gallon.

Carbonic Acid	-	12	cub. in.
Sulphuretted Hydrogen	-	20	
Sulphate of Soda	-	254.168	
Muriate of Soda	-	231.52	
———— Lime	-	7.9	
———— Magnesia	-	32	
Oxide of Iron	-	2.4	

LEAMINGTON. Sulphur Water.

The analysis of this and of most of the mineral springs of England has been performed by Dr Scudamore on the principle pointed out by Dr Murray. Dr Scudamore's results, therefore, do not require alteration.

Sulphuretted Hydrogen, quantity not ascertained.

In a Gallon.

Muriate of Soda	-	120	grs.
———— Lime	-	63.68	



Muriate of Magnesia	26.4	grs.
Sulphate of Soda	-	92.8
Oxide of Iron	-	a trace

## SALINE WATERS.

SEIDLITZ. Bergman.

*Altered to Dr Murray's View.*

In a Gallon.

Carbonate of Magnesia	20.0	grs.
————— Lime	-	6.4
Sulphate of Magnesia	1440	
————— Lime	-	40
Muriate of Magnesia	-	24

It is possible that the Muriatic Acid may rather exist in this water, in union with lime, than magnesia; but there is so little difference in solubility between the two salts, that it can scarcely be inferred which of them is present.

CHELTENHAM. Pure Saline.

The analysis by Brande and Parkes, altered to Dr Murray's View, gives the following salts.

In a Gallon.

Sulphate of Soda	-	263.76
Muriate of Soda	-	280.24
————— Magnesia	-	70.4
————— Lime	-	29.6

BATH. Scudamore.

In a Gallon.

Carbonic Acid	-	9.6	cup. in.
Carbonate of Lime	-	3.2	
Sulphate of Soda	-	44.4	
————— Lime	-	42.4	
Muriate of Lime	-	12.8	
————— Magnesia	-	12.8	
Silica	-	1.6	
Oxide of Iron	-	0.12	

LEAMINGTON. Saline. Scudamore.

In a Gallon.

Sulphate of Soda	-	62.64
Muriate of Soda	-	430.0
————— Lime	-	229.12
————— Magnesia	-	161.28
Oxide of Iron	-	a trace

LEAMINGTON. Lord Aylesford's spring. Scudamore.

In a Gallon.

Sulphate of Soda	-	263.68
Muriate of Soda	-	98.0

Muriate of Lime	-	225.92
————— Magnesia	-	41.76
Oxide of Iron	-	a trace

## BUXTON.

*On Dr Murray's View.*

(Temperature 82°.)

Carbonic Acid	-	1.5	cup. in.
Nitrogen	-	4.64	

Sulphate of Soda	-	0.63
Carbonate of Soda	-	1.62
Muriate of Lime	-	2.25
————— Magnesia	-	0.58
Carbonate of Lime	-	8.9
Extract and Loss	-	1.04

BRISTOL. Carrick.

*Altered to Dr Murray's View.*

In a Gallon.

Carbonic Acid	-	28	cup. in.
Carbonate of Lime	-	12	grs.
Sulphate of Soda	-	18.6	
Sulphate of Lime	-	5.76	
Muriate of Lime	-	3.73	
————— Magnesia	-	8.	

DUMBLANE. Analysed by Dr Murray.

In a Gallon.

Muriate of Soda	-	168	grs.
————— Lime	-	166.48	
Sulphate of Soda	-	29.6	
Carbonate of Lime	-	4.	
Oxide of Iron	-	1.36	

PITCAITHLY. Analysed by Dr Murray.

In a Gallon.

Muriate of Soda	-	101.6	grs.
————— Lime	-	161.6	
Sulphate of Soda	-	7.2	
Carbonate of Lime	-	4.	

## CHALYBEATE WATERS.

HARROGATE. Oddies Chalybeate.

Scudamore.

In a Gallon.

Carbonate of Soda	-	8.266
Sulphate of Soda	-	1.9712
Muriate of Soda	-	289.574
————— Lime	-	31.036
————— Magnesia	-	10.812
Oxide of Iron	-	2.4
Residue, chiefly Silica	-	.4



TUNBRIDGE. Scudamore.			
In each Gallon.			
Carbonate of Soda	0.2916	Sulphate of Soda	14.688
Sulphate of Soda	1.494	— Lime	18.848
Muriate of Soda	0.892	Muriate of Lime	11.424
— Lime	1.8522	— Magnesia	6.0
— Magnesia	0.29	Silica	1.12
Protoxide of Iron	1.99	Loss	1.62
Oxide of Iron	2.22	CHELTENHAM. Chalybeate. Brande and Parkes.	
Traces of Manganese, Vegetable Fibre, Silica, &c.	0.44	<i>Altered to Dr Murray's View.</i>	
Loss	0.13	In a Gallon.	
BRIGHTON. Marcet.		Carbonic Acid	20 cub. in.
<i>Altered to Dr Murray's View.</i>		Carbonate of Soda	4
In a Gallon.		Sulphate of Soda	260.37
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Sulphate of Iron	14.4	— Lime	16.48
		— Magnesia	38.4
		Oxide of Iron,	6.4

## ERRATA.

- Vol. I. p. 595, l. 14, *for* &c. It read &c., it  
 p. 654, l. 24, *for* form read forms  
 p. 675, l. 25, *for* gas read passés
- Vol. II. p. 252, l. 20, *for* 24 read 34  
 p. 526, l. 5, *for* Haune read Hauyne  
 p. 575, l. 3, *for* Resin-Asphalt read Retin-Asphalt  
 p. 551, l. 19, *for* Iganine read Igasuric  
 p. 544, l. 32, *for* Glycyrrhine read Glycyrrhizine  
 p. 666, l. 30, *for* 52 read 62  
 p. 671, l. 7, *for* 52 = 82 read 78 = 108

*b 748. last line for - 19 read - 91*



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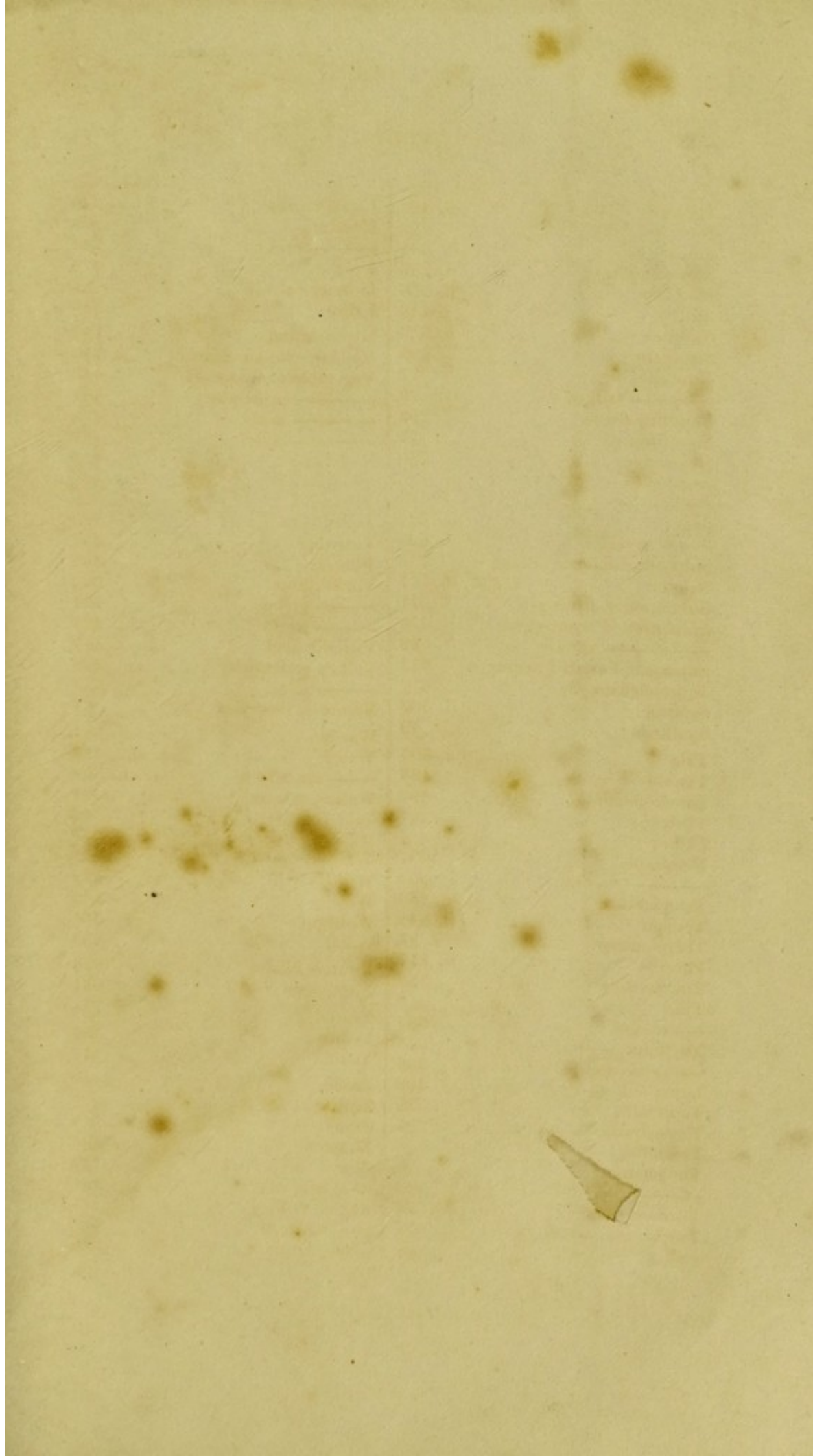


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——— ores of	363	Zircon	111
Turmeric	539	——— salts of	112
Turpentine, oil of	478	——— fossils	329
Ulinin	487		







ores







